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DEVOTED TO

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ELECTRICAL SECTION.

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MR. CLAYTON W. PIKE in the chair.

THE TRANSFORMATION OF THE ENERGY OF CARBON INTO OTHER AVAILABLE FORMS.

BY C. J. REED.

The energy of carbon, and hydrocarbons such as coal, is probably the most stable of all the forms of energy with which we are directly supplied by nature. It is the stability of this energy that has preserved it through countless ages and geological changes. It is this same stability that renders it also unavailable to man until it is brought by transformation into a more tractable or mobile form.

There are five general methods or processes known at present for converting this form of energy into the numerous forms that are directly available to man. They are:

(1) The thermal method.
(2) The thermo-dynamic method.
(3) The thermo-electric method.
(4) The thermo-magnetic method.
(5) The thermo-chemical method.

The simplest is the thermal method, in which, by simple combustion, the energy is converted directly into heat and light, and utilized for warming and illuminating.

The thermo-dynamic method consists in liberating the energy as heat by combustion, and subsequently converting the heat, through the agency of a heat-engine, into kinetic energy.

The thermo-electric method consists in liberating the energy as heat by combustion, and subsequently converting the heat into electrical energy through the agency of a thermo-electric junction.

The thermo-magnetic method consists in first liberating the energy as heat, and subsequently employing the heat to alter the intensity of a magnetic field, producing either mechanical motion or an electric current.

The thermo-chemical method embraces two varieties, each of which consists of two distinct steps or operations. One of these varieties consists in liberating the energy as heat, and subsequently causing it to be absorbed as chemical energy by a secondary substance in an endothermic reaction. The other consists in transferring the molecular energy, without transformation, from the molecules of carbon or coal to the molecules of a secondary substance, where it is less stable and consequently more available. This transfer has been accomplished only at high temperatures and, therefore, it requires the expenditure of some energy in the form of heat.

The second step which follows the thermo-chemical process consists in transforming the energy of the secondary substance into electrical energy through the agency of a galvanic cell.

It will be seen that all these known methods are thermal methods to a greater or less extent; that is, they all require the whole or a portion of the energy concerned to be transformed into heat in the process of becoming available.

Pure carbon manifests no affinity for any known substance at low temperatures. It may be made to combine with oxygen directly only at temperatures above 250° C. Indirectly, and by expending upon it the energy of powerful oxidizing agents, or the energy of an electric current, it may be slowly oxidized at low temperatures. But all attempts, without exception, to obtain energy from carbon at low temperatures have totally failed.

Numerous compounds of carbon, such as carbon monoxide and various hydrocarbons, are easily oxidized at low temperatures by powerful oxidizing agents; but such reactions have not evolved available energy.

The best method of transforming the chemical energy of carbon or coal depends largely upon the form in which the energy is desired. Where, for instance, the desired form of energy is unconfined heat of moderate degree or intensity, the thermal method, by combustion in air at a high temperature, is both practically and theoretically perfect in efficiency.

Where the energy is desired in some other higher form than heat of moderate intensity, it may be obtained from carbon only at a great loss, determined in each case by particular conditions.

If heat of high intensity is the desired form, it may also be obtained directly by thermal combustion, but only at a greatly reduced efficiency, since by this method all heat evolved, which is not up to the proper intensity, is rejected and unavailable.

With the thermo-dynamic method, in which the heat is transformed into mechanical motion or kinetic energy by the alterations in volume of a working substance, the maximum efficiency is limited, by the second law of thermodynamics, to the difference between the initial and final temperatures divided by the initial temperature. By this method an efficiency of from 3 to 10 per cent. is generally

obtained. The method is so generally understood that it needs no further mention here.

In the thermo-electric method the efficiency of transformation, in addition to being limited by the second law of thermo-dynamics, is limited also to the difference between the Peltier effects at the hot and cold junctions divided by the Peltier effect at the hot junction, an expression which is in the same form as that for the maximum efficiency of a thermo-dynamic process.

Comparing these two methods, we have in the thermo-dynamic transformation

$$E = \frac{T - T'}{T},$$

in which T and T' represent respectively the absolute temperatures at which heat is received and rejected in a heat engine, E being the maximum efficiency.

In the thermo-electric transformation, we have, in addition to the above limitation, the further limitation

$$E = \frac{P - P'}{P},$$

in which E is the maximum efficiency, and P and P' represent respectively the Peltier effects at the hot and cold junctions of a thermo-electric battery. A thermo-electric circuit may be so chosen that the Peltier effect at the cold junction is zero, though this is not generally practicable. In that case the maximum efficiency would not be limited by this law to less than

$$\frac{P}{P},$$

or 100 per cent.

Unfortunately there are other and more important limitations to this method than the theoretical ones. These are of so serious a nature that the thermo-electric method has not yet equaled, nor even remotely approached in efficiency, the thermo-dynamic method.

Perhaps the greatest drawback to the thermo-electric method of transformation is the fact that there is no known substance that fulfils the requirements of a perfect working

substance, even to a very small extent. A perfect thermo-electric substance must be a perfect conductor of electricity and a perfect non-conductor of heat. But we find in nature that all substances are either very poor conductors of electricity, or else very good conductors of heat. The result of this and other limitations is that no thermo-electric couple has yet been produced which can transform more than a small fraction of 1 per cent. of the heat applied to it into electrical energy.

The principal difficulties of this method may be illustrated by reference to *Fig. 1*, in which *C* represents the cold junctions, and *H* the hot junctions of any thermo-electric battery. All heat that passes by conduction from the hot to the cold junction is necessarily wasted. Hence, the substances should be the poorest conductors of heat. The internal resistance of the battery will be the sum of the

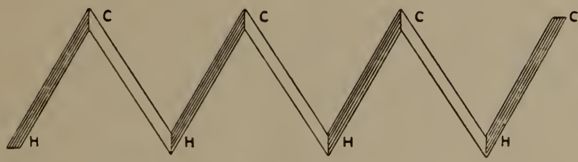

FIG. 1.

resistances of all the bars, *HC*, placed in series. Hence, the substances employed should be the best possible conductors of electricity. But all good conductors of electricity are also good conductors of heat. It is, therefore, impossible to gain any great advantage by choosing a substance with reference either to its thermal or to its electric conductivity; because any advantage that may be gained through increased electric conductivity will generally be counterbalanced by the loss through increased thermal conductivity.

For the same reason it is useless to attempt, with any given substance, to reduce the electrical resistance of the thermo-electric battery by increasing the cross-section of the conductors. Any such decrease in resistance will be counterbalanced by a proportionate increase in the loss through conduction of heat.

Again, we cannot gain any advantage in attempting to

reduce the heat conduction by increasing the distance between H and C, since this would proportionately increase the internal resistance. Therefore, the efficiency evidently cannot be materially increased by altering the form or dimensions of the elements composing the battery.

The thermo-electromotive force between C and H, with every known couple, is very small, ranging from $\frac{1}{1000}$ to $\frac{1}{1000000}$ volt for every degree of difference in temperature between H and C, and is proportional to this difference. But here, again, increasing the temperature of the hot junction, or diminishing the temperature of the cold junction, while it does increase the E.M.F., can result in no improvement in efficiency, since increasing the difference in temperature between the junctions increases, in the same ratio, the rate at which heat will pass by conduction from the hot to the cold junction, where it is rejected without undergoing any change except degradation of temperature.

Heat is continuously flowing from the hot to the cold junction, whether the circuit be open or closed. Therefore, the condition of maximum efficiency of transformation in a thermo-electric battery is that in which the maximum current is flowing, or when the external resistance is zero. This must mean that we can attain maximum efficiency of transformation only when the battery is short-circuited and the current is entirely used in heating the battery itself, the same as though there were no transformation.

In view of these facts, it seems to me that there is little hope for any radical improvement in this method of transformation. Nevertheless, we read, from time to time, accounts of improved thermo-electric batteries (about to be perfected) that are to have a greater efficiency than any other method of transformation.

In the thermo-magnetic method of transformation the energy is first liberated as heat, and the heat used to vary the intensity of magnetization in a magnetic body, with the production of either mechanical motion or an electric current. This method was discovered by Thomson and Houston in 1879, and was communicated to the Franklin Institute at that time; but the results obtained by this method, up

to the present time, are commercially insignificant. As the process depends entirely upon the absorption and rejection of external heat, it is evidently limited by the second law of thermo-dynamics. No attempt has yet been made to apply this method in practice.

The thermo-chemical method of transformation is the only known method by which even a part of the energy of fuel may be brought into an available form without a primal degradation into heat. In this process, energy may be *transferred*, without transformation, directly from the molecules of fuel to the molecules of a secondary substance in which it is less stable.

In carrying out this process it is necessary to develop as heat only so much energy as may be required to maintain the substances involved in the operation at the temperature at which the transfer takes place, unless the reaction is endothermic, in which case additional heat for absorption must be supplied.

If the reaction be exothermic, the heat required for maintaining the temperature, or a part of it, may be derived from the reaction itself after this is once started. If it be endothermic, there must be liberated as heat, in addition to the amount necessary to maintain the proper temperature, an amount equal to that absorbed in the reaction. In this case, a part of the transferred energy passes through the form of heat.

The general method of carrying out the thermo-chemical process is to heat the fuel in a closed chamber to a high temperature in contact with a chemical reagent capable of acting upon the fuel in such a manner as to absorb the energy. The only reagents heretofore employed for this purpose are oxides, and generally metallic oxides, which, in the reaction, become reduced to the metallic state by oxidizing the fuel.

The difference between the formation heat of the oxide employed and that of the oxide formed represents an amount of energy which must necessarily be developed in the form of heat, otherwise the reaction could not occur. If the formation heat of the oxide employed be greater than

that of the oxide formed, the difference is negative, and must be supplied in the form of heat absorbed from an external source. If it be less, the difference between the two is evolved as heat of combustion.

We find, therefore, two limitations to the efficiency of the thermo-chemical process: (1) The loss of the heat necessary to raise the materials to the temperature at which reaction takes place, and to maintain them at that tempera-

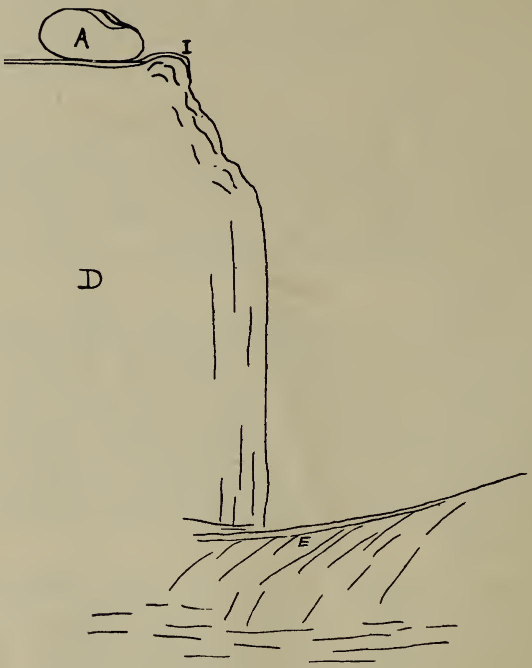

FIG. 2.

ture. (2) The heat necessarily evolved, and which is the equivalent of the difference between the formation heat of the reagent and that of the oxidation product. In cases where this latter heat is evolved by the reaction (that is, where the reaction is exothermic), it may generally be employed to help maintain the temperature. Where it is absorbed by the reaction (reaction endothermic), it must be obtained from without by the combustion of an additional amount of fuel. The result is that, in general, only exother-

mic reactions are easily and economically performed. It follows, also, that the more exothermic a reaction is, the more easily it will be maintained after starting. The more nearly athermal a reaction is, the greater will be the possible efficiency of the transfer from one substance to another, especially in cases where the reaction takes place at a low temperature.

In order to illustrate more clearly the meaning of the above statements, I have arranged a comparison to represent graphically the analogy between chemical energy or molecular potential energy, and ordinary molar potential energy, or the potential energy of elevated masses of matter. I may add that the two are strictly comparable, being not merely similar, but identical.

In *Fig. 2* is represented an elevated mass of rock, *A*, lying on the edge of a plateau on the table-land, *D*. At *I* is an obstruction which prevents *A* from rolling over the precipice into the ravine at *E*. In its elevated position, *A* contains a certain quantity of potential energy, due to its elevation above, and the possibility of its descending to, *E*; or, in other words, due to a certain quantity of separation that has been effected between *A* and the center of the earth.

This energy is in a very stable and unavailable condition. It is held by the obstruction, *I*, which prevents *A* from undergoing any change. This energy we may compare to the energy of separation which exists between a molecule of free oxygen and one of free carbon. The separation of an atom of carbon from two atoms of oxygen, or the reaction

$$CO_2 = C + O_2$$

requires as definite a quantity of energy as does the separation of a pound of rock to a distance 100 feet farther from the earth's center. The only difference between the two cases is that one is a molar, the other a molecular separation. In the one case there is a separation of visible masses, in the other a separation of invisible molecules. In either case, the potential energy acquired is equal to the work done in effecting the separation.

The molecular separation in 1 pound of free carbon is equal to the molar separation of raising 1 ton to a height of 1 mile. This comparison gives a very fair idea of the vast amount of separation or potential energy there is in a pound of carbon. A pound of hydrogen in the ordinary gaseous state contains about four times this amount.

A pound of matter falling without obstruction from an infinite distance to the earth's surface, would acquire a velocity of 7 miles per second, and would strike with an energy of 10,600 foot-tons. But the molecular energy of a pound of hydrogen gas, which is liberated in combining with oxygen, is 23,600 foot-tons. In other words, the chemical energy of hydrogen gas, if applied to its own mass to give it an upward velocity, is two and one-quarter times what would be necessary to project it to an infinite distance whence it could never return.

Returning to our mass of matter, *A*, *Fig. 2*, we find that the only way we can get the energy of this body into an available form is to allow it to descend to *E*. To accomplish this, we must apply some external energy to it, either to remove the obstruction or to raise the body, *A*, high enough to allow it to roll over the obstruction. Its energy of position will then be rapidly transformed into kinetic energy, which will, in turn, after reaching *E*, be transformed into heat. After the obstruction has been overcome, and the mass has begun to descend, its progress cannot be arrested, except by the application of more energy or by some other obstruction.

Similarly, the energy of carbon is held back by a molecular obstruction that prevents it from undergoing a chemical change, or a fall of molecular potential, until sufficient external energy has been applied to overcome the obstruction. A mass of carbon may be allowed to stand in contact with atmospheric oxygen, or even pure oxygen, for ages, and not a single atom will oxidize, though the affinity of the carbon for the oxygen atom is enormous. After the separation of carbon from oxygen has once been effected, the carbon atoms unite with one another, and their mutual attraction, though small, constitutes an insuperable obstruc-

tion to the union with oxygen. This obstruction may be removed, however, by the application of a small amount of external energy in the form of heat, which breaks up the carbon and oxygen molecules and allows the atoms to exercise their affinities for each other. This is well illustrated in the kindling of a fire by applying a lighted match to a shaving. After this reaction has begun it proceeds rapidly, as in the case of our falling elevated body, until all the energy represented by the reaction is converted into heat, and the temperature rises to a point limited only by the specific heat of the products of combustion and the conditions of radiation.

The great drawback to all thermal methods of transformation is the difficulty of modifying this process of combustion, after it has once started, in such a manner as to prevent the degradation of all the energy into heat, and to cause a considerable portion of it to be changed directly into available forms.

In *Fig. 3* is shown, in connection with our elevated body, a wheel and axle, *C*, to which it is desired to apply some of the energy of *A*.

This may be done in a simple manner by allowing *A* to descend and strike *G*, the short end of a lever pivoted at *H*, on the longer end of which, at *F*, is a small mass of stones. The stones are projected upward with a velocity greater than that acquired by the falling body, and some of them drop into the scale-pan, *C*, attached to the rope which operates the wheel and axle. The weight of these stones causes the pan to descend and the axle to revolve, again converting potential into kinetic energy, which is now available.

This method of transforming the potential energy of *A* into the kinetic energy of the wheel and axle is obviously very inefficient, and seems like letting down energy for the sake of raising it up again. It is, however, not so inefficient as the thermo-dynamic method of converting energy of coal into available forms, as generally practised and illustrated in the ordinary steam engine.

Absurd as the arrangement shown in *Fig. 3* seems, it could undoubtedly be made, by a suitable refinement of the

mechanism, to operate with an efficiency of more than 90 per cent., which is incomparably greater than anything ever yet attained by any method of transforming energy of fuel into kinetic energy.

The reason for this, I think, is obvious. It is this; that in the transformation of molar potential energy into other

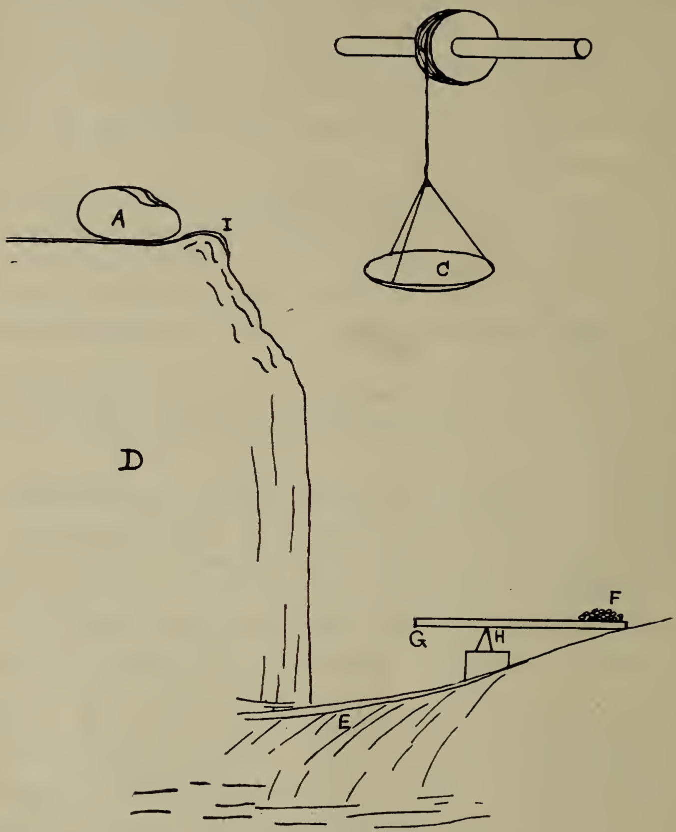

FIG. 3.

forms, there is no necessity for its primal degradation into heat; whereas, in the case of the molecular potential energy of all substances commonly called fuel, there is no known method of transformation except by a thermal or partially thermal process.

It is my purpose to show that, by a proper application of

the thermo-chemical method, followed by the galvanic process, it is possible to transform the molecular energy of fuel with an efficiency comparable to that of molar transformation, and to do so without resorting to any extreme or abnormal conditions of temperature.

To follow out the comparison instituted above, this method may be illustrated in *Fig. 4*.

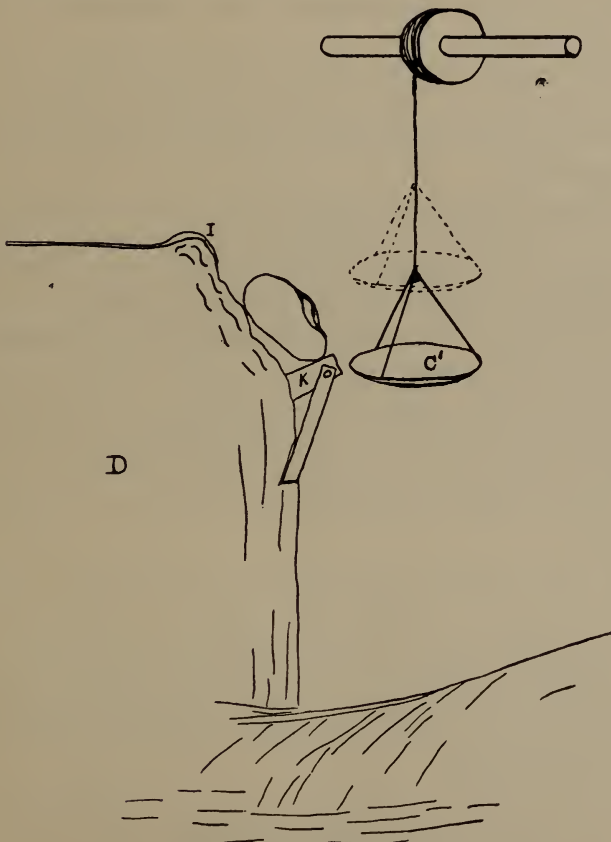

FIG. 4.

We first apply a small amount of energy to the scale-pan to bring it down to C'. An artificial obstruction is also placed at K, before removing I, to arrest the motion of the falling body and divert it into the scale-pan. A large part of the potential energy of A is thereby transferred directly

to the scale-pan, instead of being first transformed into kinetic energy, which would still be unavailable. The letting down of the body from its original position to the point *K* may be compared to a chemical reaction in which carbon undergoes combination in the formation of an unstable or combustible carbon compound, without giving up all its energy. The transfer of the mass from *K* to the scale-pan may be compared to an athermal, or nearly athermal, reaction.

In this manner we provide, for the molecular potential energy of carbon, a channel through which a large part of it may be transferred directly to another substance without transformation.

Sufficient external energy in the form of heat is first applied to the carbon, to break up its molecules and start its energy on the downward course into heat. Instead of allowing the reaction to proceed without obstruction, it may be partially arrested by the intervention of a suitable body to which a large portion of the chemical energy is directly transferred. This intermediate body acts in the same manner as the scale-pan in our illustration, to temporarily retain the energy in an available and controllable condition, from which it may be transformed, at will, with a very high efficiency.

We have a familiar illustration of the thermo-chemical-galvanic method of transformation in the ordinary galvanic battery, in which metallic zinc acts as the intermediate body or working substance. For certain applications, such as ringing electric bells, this method has been in successful competition with other processes of transforming energy for nearly a century.

The first step in the process is to mix carbon with zinc oxide in a closed retort. Zinc oxide has a small amount of available molecular potential energy, but much less than metallic zinc. We apply to the retort, from an external source, sufficient heat to raise the temperature of the mass to about 1,100° C. At this temperature the carbon is capable of taking oxygen from the zinc oxide, and thereby undergoing partial combustion, a part of its energy being transferred directly to the zinc.

The following equation represents the change:

$$ZnO + C = Zn + CO$$

The products of this reaction, Zn and CO, contain respectively 85,000 and 67,000 units of molecular energy, the original C containing 97,000. There must have been absorbed, therefore, from without, 55,000 units of heat. Of the 97,000 contained in the carbon, 30,000 have been transferred to the zinc, while 67,000 units remaining with the CO are not available for further reaction. We have, therefore, in the zinc, 30,000 of the 97,000 units contained in the carbon, or about 31 per cent., as the possible maximum efficiency of the first step in the process. The next step consists in re-oxidizing the zinc in presence of an electrolyte with evolution of electrical energy in the galvanic cell.

Considering zinc merely as a transformer of energy, without any reference to cost of labor and materials, its efficiency in practice, at the very best, can scarcely exceed 2 per cent.

The amounts of coal required in practice for the reduction of 1 pound of zinc from the ore are given as follows:

	Pounds.
Roasting	·34
Reduction	1·25
Firing (external heat)	5·00
Total	6·69

This represents an expenditure of about 48,000 thermal units in effecting the reduction of 1 pound of zinc. The reduced zinc acquires only 1,300 units, and if it were all available in a galvanic battery, its efficiency as a transformer would be

$$\frac{1,300}{48,000} = 2{\cdot}6 \text{ per cent.}$$

But the reduction of zinc to the metallic state is not the only step in the process. The metal must be re-melted, cast, rolled, amalgamated and properly connected in the cell. The mechanical preparation generally entails a loss of 5 per cent. In the final step the zinc is not all utilized. If

the zinc be not well amalgamated, there is generally lost by local action from 50 to 90 per cent. Even if the zinc be well amalgamated, the mercury tends to collect at the lower part of the plate, and the principal action then takes place at the surface of the solution. At this point the plate soon becomes eaten through, and breaks, leaving two pieces of practically worthless scrap zinc, one in the bottom of the cell and the other hanging above the solution. It is safe to say that in actual practice of all kinds, not less than 50 per cent. of the zinc of primary batteries finally deposits its expensive energy in an unavailable scrap heap. Assuming this figure to be roughly correct, we have the net efficiency of zinc as a transformer reduced to 1·3 per cent.

The final step in the transformation is the oxidation of zinc upon closure of the battery circuit. This should take place at a temperature below that at which the solution will attack the zinc on open circuit.

If zinc and atmospheric oxygen were the only substances required in oxidizing the zinc, the only limit to the maximum efficiency of this step in the process would be 100 per cent. But as a matter of fact we cannot oxidize even metallic zinc directly by atmospheric oxygen in such a way as to obtain electrical energy from it. It has little more affinity for oxygen at low temperatures than carbon. Its energy may be transformed into electrical energy only by taking advantage of its affinity for other substances with which it forms "salts," instead of its affinity for oxygen. Such reactions take place in the cold readily and evolve greater energy than could be obtained by direct oxidation. Carbon, unfortunately, has no such affinities, and forms no such compounds as *salts*.

We have for heats of formation in solution:

	Units.
For zinc oxide, $Zn + O = ZnO$	83,000
" zinc sulphate, $Z + O + SO_3 = ZnSO_4$	108,000
" zinc chloride, $Zn + Cl_2 = ZnCl_2$	113,000

Unfortunately, the zinc salts formed as products of these reactions, $ZnSO_4$, $ZnCl_2$, etc., are not the original transforming substance, ZnO, and cannot be again reduced to metallic

zinc without the expenditure of vastly greater amounts of energy than that required to reduce ZnO. So great is the energy required for the reduction of the sulphate, that, if we were actually to carry it out in practice, our efficiency of 1·3 per cent. would have to be again divided by a large number. Heretofore, these products have always been thrown away in preference to reducing them.

Another serious loss in the zinc battery is that these by-products, which must be rejected, carry with them into the scrap heap, not atmospheric oxygen, but the (SO_4), Cl, or other expensive materials used in oxidizing the zinc.

The process, when operated with zinc as a transforming substance, is, therefore, not a complete or cyclic process, since the transforming substance never passes through the same condition twice. It is really more a process of transforming matter than one of transforming energy.

Any process of transforming the energy of fuel is not complete and cannot successfully compete with thermo-dynamic processes on a large scale, if it necessitates the continuous consumption of any material other than the fuel itself and air, or if it finally rejects as by-products any materials besides the products of combustion.

I have taken zinc as an illustration of a working substance through which the energy of fuel may be transformed by the thermo-chemical method, not because it is a suitable substance, but because of our familiarity with it.

While zinc may be profitably employed as a transformer in this manner for particular cases, such as gas lighting, bell-ringing, etc., where comparatively insignificant quantities of energy are to be transformed, it cannot compete in efficiency on a large scale with thermo-dynamic methods.

The commercial failure of the galvanic battery to compete with steam is not, however, due to any inherent defect in the thermo-chemical-galvanic method of transformation, but entirely to the fact that zinc, as pointed out above, is not a suitable working substance to use as a transformer.

The objections to the behavior of zinc as a transforming substance teach us what is to be desired and what is to be avoided in seeking an ideal transforming substance. They

indicate, also, that there is little hope for improvement in the method, so long as we employ zinc or any similar metal as a transformer.

I believe we may go even a step further and say that there can be no radical improvement in this method so long as the transforming substance constitutes at the same time one of the electrodes of the battery.

A galvanic battery, like any other apparatus, in order to be of great practical applicability, should be capable of maintaining its mechanical integrity. If we were to succeed even in substituting carbon for zinc in the galvanic battery of ordinary form, I believe it would result in no material saving; for carbon in a good mechanical form is as expensive as zinc in the same form. The most serious defect in the galvanic battery, as a mechanism for transforming energy, lies in the fact that it can operate only by destroying its own mechanical integrity, to replace which is much more expensive than the mere materials of which it is built up.

What would be thought of the commercial utility of a steam engine that derived all its energy from the oxidation of its own piston-rod; or of a steam boiler that could utilize no energy except what was derived from the oxidation of its tubes; or of a dynamo that could supply no electric current except what might be derived from the burning of its brushes or commutator?

Yet this is exactly the sort of mechanism we have in all galvanic batteries. The only energy that can possibly be evolved is that which comes from the mechanical destruction of the battery itself. This seems to me a much more serious difficulty than any difficulty arising from inefficiency in the actual transformation.

Nevertheless, the galvanic cell is the only known instrument by which chemical may be directly transformed into electrical energy, and there is no theoretical limitation to its possible efficiency.

The ideal cell should consist of two indestructible, or reasonably permanent, conducting solids, in contact with a liquid electrolyte. The electrolyte should consist of two

solutions, separated by a porous partition, through which one of the solutions flows. Each of the two solutions should contain a chemical reagent capable of combining with the other, on contact of the solutions, in an exothermic reaction.

The working or transforming substance should be capable of acting upon carbon at as low a temperature as possible, without evolution or absorption of much energy, and with formation of an unstable carbon compound easily oxidized to CO_2. The working substance should also be capable of combining with atmospheric oxygen at as low a temperature as possible, without the evolution or absorption of much energy, and with formation of an unstable oxygen compound. These two compounds of the transforming substance, one of carbon and one of oxygen, should constitute the active chemical reagents of the cell, and should be capable of uniting on contact in the cold electrolyte, with formation of CO_2 and precipitation of the transforming substance in its original free state. Arrangements should be such that the exhausted electrolyte may continuously flow out of the cell and regenerated material flow in.

Such a set of reactions would be represented by the following equations, in which T represents one combining equivalent of the transforming substance, C, an equivalent of carbon, and O, an equivalent of atmospheric oxygen:

$$T + O = TO. \qquad (1)$$

$$C + T = CT. \qquad (2)$$

$$2TO + CT = CO_2 + 3T. \qquad (3)$$

In equation (1), TO represents the secondary reagent produced by the action of T upon atmospheric oxygen, and CT, in equation (2), represents that produced by the action of T upon carbon. All three of these reactions should be exothermic, and the first two as nearly athermal as possible.

The reagents TO and CT are the active materials which are brought in contact in the battery. Equation (3) represents the reaction that takes place in the discharge of the battery, CO_2 and T being the products of discharge. CO_2, identical with the product of combustion of carbon in air, is

rejected, while T is the regenerated working substance, and may be used an indefinite number of times.

It will be seen that the only substances used in these reactions are carbon, atmospheric oxygen and the transforming substance. The substances produced are carbon dioxide and the regenerated transforming substance.

The question naturally arising at this point is, whether there can be found in nature a transforming substance answering these ideal requirements.

In answer to this question, I find there are a number of substances, all answering the requirements to some extent, some to a very great extent. A surprising fact is that these substances, instead of being highly electro-positive metals,

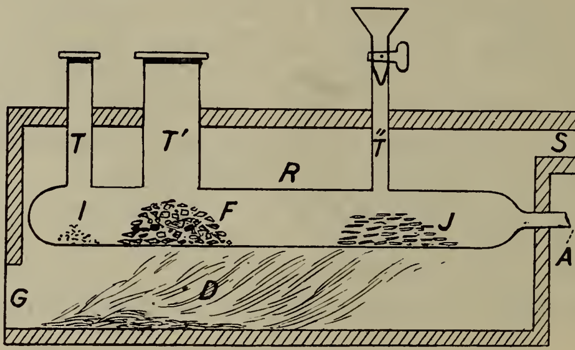

FIG. 5.

like zinc, iron, magnesium, etc., are not metals at all, being, without exception, non-metallic substances. By non-metallic, I mean that they do not, at any stage of the cycle of chemical changes through which they pass, come into a metallic state. In most cases the best results are obtained, not by following exactly the formula laid down in equations (1), (2) and (3) above, but by indirectly bringing about an equivalent series of reactions.

To illustrate this cyclic method of thermo-chemical transformation, we shall take as our transformer the two substances, sulphur and water; as fuel, carbon, and as oxidizing agent, atmospheric oxygen.

The first step in the process is the combustion of sulphur

in the air, with production of sulphur dioxide, SO_2, and the evolution of 71,000 units of heat, as represented in equation (4).

$$S + O_2 = SO_2 + 71{,}000 \qquad (4)$$

The SO_2 formed by this reaction is passed through water, which absorbs it and forms the oxidizing electrolytic solution. Some sulphuric acid may be added to increase the conductivity.

The heat developed by the combustion of the sulphur is applied to a retort, *R*, shown in *Fig. 5.* Carbon is admitted to this retort at *F*, through the tube *T′;* sulphur is admitted at *I* through the tube *T;* and water is allowed to drop upon a pile of broken crockery or stones at *J.* The sulphur is burned at *D* with air supplied through the opening *G.* The SO_2 passes out at *S.* The heat from the sulphur burning at *D* heats the carbon, *F*, to a dull-red heat. The sulphur, *I*, is vaporized, and, passing over the heated carbon, forms carbon disulphide, according to the following equation:

$$\left\{\begin{matrix} 97{,}000 \\ C \end{matrix}\right\} + \left\{\begin{matrix} 142{,}000 \\ S_2 \end{matrix}\right\} + \left\{\begin{matrix} 19{,}000 \\ \text{Heat} \end{matrix}\right\} = \left\{\begin{matrix} 258{,}000 \\ CS_2 \end{matrix}\right\}$$

The carbon contains 97,000 and the S_2 142,000 units of molecular potential energy referred to oxygen, and the CS_2 formed contains 258,000. Hence there must be absorbed in this reaction 19,000 units of external heat.

The CS_2 vapor comes next in contact with the steam and hot bricks at *J*, where double decomposition occurs with the absorption of 14,000 units of external heat and the formation of hydric sulphide and carbon dioxide, represented as follows:

$$\left\{\begin{matrix} 258{,}000 \\ CS_2 \end{matrix}\right\} + \left\{\begin{matrix} 0 \\ 2H_2O \end{matrix}\right\} + \left\{\begin{matrix} 14{,}000 \\ \text{Heat} \end{matrix}\right\} =$$

$$= \left\{\begin{matrix} 272{,}000 \\ 2H_2S \end{matrix}\right\} + \left\{\begin{matrix} 0 \\ CO_2 \end{matrix}\right\}$$

The final products, H_2S and CO_2, pass out at *A*. The H_2S may be absorbed in water, which becomes the reducing

electrolytic solution, or it may be used in the gaseous state.

We have now expended the energy of

	Units.
3 equivalents of S = 3 × 71,000	= 213,000
1 equivalent of C	= 97,000
Total	= 310,000
We have transferred into H_2S	= 272,000
Lost as residual furnace heat	= 38,000

The next operation is to bring the SO_2 and H_2S together in a manner such that electrical energy will be evolved, and the transforming substances, sulphur and water, will be regenerated.

In the well-known reaction between SO_2 and H_2S in the gaseous state, we have a most beautiful example of spontaneous combustion at low temperatures. It is represented by the following equation:

$$\left\{\begin{matrix} 270{,}000 \\ 2H_2S \end{matrix}\right\} + \left\{\begin{matrix} 0 \\ SO_2 \end{matrix}\right\} = \left\{\begin{matrix} 0 \\ 2H_2O \end{matrix}\right\} + \left\{\begin{matrix} 213{,}000 \\ 3S \end{matrix}\right\} + \left\{\begin{matrix} 59{,}000 \\ \text{Heat or Electrical Energy.} \end{matrix}\right\}$$

Our final products are the original 2 molecules of water and 3 molecules of sulphur, which were used as the transforming substances.

The sole function of these substances has been to receive 59,000 units of the 97,000 units of energy contained in an atom of carbon, and deliver it, in a reaction that takes place at a low temperature, even in cold solution, either in the form of heat, or of electrical energy without heat.

An apparatus in which this final reaction may take place is shown in *Figs. 6* and 7. In *Fig. 6* the carbon electrodes, *C*, are in contact with one solution, either the SO_2 or the H_2S, while the carbon electrodes, *C′*, are in contact with the other solution. The two solutions are separated by the porous cups, *E*. The solution within the cups should be at a higher level than that outside.

The SO_2 and H_2S may be delivered in the gaseous state under pressure to the apparatus shown in *Fig. 7*. One gas is delivered through the tubes, *P*, to the interior of the hollow carbon electrodes, *C*, and the other through the tubes, *P'*, to the hollow carbon electrodes, *C'*, both being immersed in dilute sulphuric acid. The electric circuit is completed by the wires, *W* and *W'*. The pressure should be sufficient to force the gases through the pores of the carbon electrodes into the electrolyte in which they dissolve. The regenerated

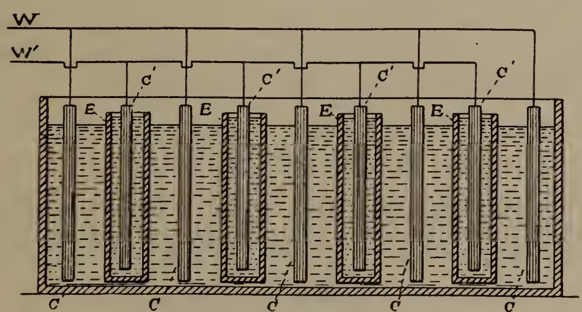

Fig. 6.

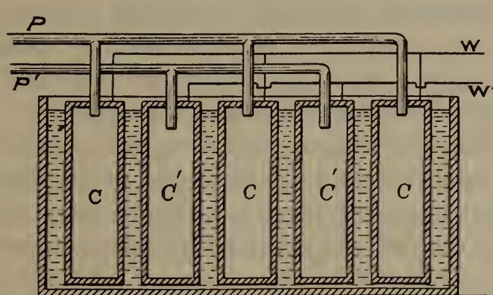

Fig. 7.

sulphur is precipitated as a white powder, and may be separated by filtration or settling.

The balance sheet of our energy now stands:

1 atom of carbon expended	97,000	
3 atoms of sulphur expended	213,000	
3 atoms of sulphur regenerated		213,000
Heat lost in furnace		38,000
Transformed into electrical energy		59,000
	310,000	310,000

The 3 atoms of sulphur regenerated are exactly equal to the 3 atoms used, and hence they may be eliminated, leaving, as the net transaction, 1 atom of carbon expended and 59,000 units transformed into electrical energy, or a maximum efficiency,

$$E = \frac{59{,}000}{97{,}000} = 61 \text{ per cent.}$$

The actual attainment of 61 per cent. efficiency would require, however, that the final or galvanic step in the process should take place without loss. While this is a theoretical possibility, it cannot be expected in practice. The theoretical electromotive force of the cell would be

$$\frac{59{,}000}{4 \times 23{,}260} = 0{\cdot}63 \text{ volt.}$$

The highest electromotive force I have yet obtained on closed circuit is ·36 volt, corresponding to an efficiency of

$$61 \times \frac{\cdot 36}{\cdot 63} = 35 \text{ per cent.}$$

So far, we have considered only the chemical reactions involved in the process of transformation. There are also physical changes that must not be ignored. I refer to changes of state which the substances undergo. Carbon in burning changes from the solid to the gaseous state. In stating its combustion heat as 97,000 units, the heat necessary for this change of state is already taken into account. The same is true of the sulphur, 71,000 units being evolved as heat in addition to the amount of heat required to convert the solid sulphur into the gaseous state. The 2 molecules of water, which enter into the reaction in the liquid state, do not supply any molecular energy, and an additional 19,200 units must, therefore, be supplied in the furnace to convert this water into steam. This energy will again be evolved when the H_2S and SO_2 liquefy by solution in water; but it certainly could not be available in the apparatus shown in *Fig. 6*, since the gases are brought into solution before coming into the battery. Whether any of this energy would be available in the apparatus shown in

Fig. 7, I am not prepared to state. This 19,200 units of heat of vaporization might, in practice, be obtained from the 38,000 necessarily dissipated in the furnace, and need not, therefore, necessarily affect the figures given above for efficiency.

While I do not regard this particular process of carrying out the method as being commercially of great importance, I believe it indicates the only direction in which we are likely to attain any great improvement over thermo-dynamic methods.

I cannot close without referring to the so-called direct method of conversion of the energy of carbon into electrical energy. I shall not detain you long with this method, as no evidence has yet been published which indicates that it has ever been accomplished. The claims for such a method have generally been made solely upon the indications of a voltmeter attached to a carbon electrode, in combination with chemical reagents, which, alone, were sufficient to account for the indications. In some cases, also, thermo-electric junctions, in which carbon and a metal were joined by a fused salt, have been mistaken for galvanic batteries.

As for the development of electrical energy by the combustion of hydrogen and certain gaseous hydrocarbons in contact with an electrolyte and platinum-black, it must be remembered that these substances are neither carbon nor original fuel, and that their energy is obtained, by a thermo-chemical process, from the energy of fuel.

The reading of the paper was followed by experiments, which showed the reaction between H_2S and SO_2, under various conditions. In one experiment, a modification of the apparatus, shown in *Fig.* 7, was used, and an electromotive force was obtained, on closed circuit, of ·32 volt.

Several experiments were also performed with an extemporized Jacques battery, all of which showed that the Jacques battery is a thermo-electric, and not a galvanic battery.

It was shown that, at low temperatures, while the caustic alkali contained considerable water, the carbon was positive to the iron; but that at a high temperature, after the alkali had become highly de-hydrated, the carbon was negative to the iron.

The carbon rod was replaced, successively, by rods of brass, copper, German-silver and iron, without appreciably affecting the result, and a current of illuminating gas was passed into the fused alkali in place of the current of air employed by Jacques. The result was unchanged, showing that the action of the current of air was not to produce oxidation, but to cool the upper layer of the alkali.

UTILIZATION OF THE ANTHRACITE CULM HEAPS IN THE PRODUCTION OF POWER.*

By Nelson W. Perry, E.M.

The doctrine of the survival of the fittest has become so universally accepted as to be its own best illustration of its truth.

A process, a type or a theory, can only prevail as it proves its better adaptability to the conditions, than do those with which it competes; but no process or type—and we may also say no theory—can be considered perfect, because conditions are constantly changing, and that which was best yesterday may be supplanted by something better suited to the environment of to-day. Thus the need for invention ever exists, even in the face of supposed perfected conclusions.

In the mad struggle of the present day for supremacy, no one who would be in the race can afford to be without the assistance of the best thought of the times, and it is this want that has made our times the engineering era of the world's history.

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* A lecture delivered before the Franklin Institute, March 13, 1896.

If I might suggest a comprehensive definition of the engineer, I would say that he is one who makes two blades of grass grow where but one blade grew before. He is the skilled adapter of the means at hand to the desired end.

In the history of our early gold and silver mining, material was thrown away which produced fortunes for those who came after, and in the history of our coal mining, fuel has been discarded, which in the future is to turn the wheels of industry; and that which actually constituted a drain upon our resources is henceforth to contribute to our wealth.

The most significant indication of the progress of engineering science is the rapidly increasing directions in which hitherto waste products are being turned to account, and it is in one of these directions that I would direct your thoughts to-night.

The most potent factor in the march of civilization, undoubtedly, is the cheapening of our methods of producing power; and, perhaps, second only to this in importance is the improvement in methods of transmitting this power from the point where it can be produced to the best advantage to the point where it can be utilized most advantageously.

While it is true that there are some industries in which the cost of power forms so considerable a factor in the cost of the manufactured article as to be controlling, it is, nevertheless, true, that if we consider the manufacturing industries as a whole, the cost of power amounts to only about 10 per cent. of that of the product; and in many cases, therefore, it is cheaper to bring the power to the raw material than the latter to the former.

Niagara, with its enormous water-power now partly utilized, has already attracted the attention of the whole world, and the promise of cheap power is held as an inducement to outside manufacturers to locate there or in the vicinity. So interesting to the commercial world has been this feat, that, were tumbling waters sentient beings, we might imagine every mountain stream trembling lest its time to wear the yoke should be near at hand. But

vast as is the available power at Niagara, and numberless as are the other possible water-power centers of lesser magnitude, they cannot, even all combined, meet every industrial requirement. Other neglected sources of cheap power have been sought for and found, and these, too, will be utilized.

The coal mines, from the time of their opening, have been throwing away material which this generation is beginning to appreciate as of value, and as the old tailings from the silver mines have been worked over with profit, we are beginning to work over the culm piles from the coal mines and to appreciate their value.

When we bear in mind that every ton of these culm accumulations not only has been paid for by those who have used the more marketable coal from which it was discarded as refuse, but also is occupying real estate which is growing more valuable every day, we see that in these accumulations there is a source of potential energy which, if less inexhaustible than that of Niagara, is still enormous and quite as available.

Since it has not only been paid for, but is a cumberer of the ground, and furthermore has been proved to be a valuable fuel when properly utilized, the question has naturally arisen: how may it be utilized most effectively for the generation of power?

As to the available quantity of this culm, perhaps the most reliable estimate is that given by the commission appointed by the Governor of Pennsylvania to investigate and report on the waste of coal. This commission, at the date of its report, May 20, 1893, consisted of Eckley B. Coxe, Heber S. Thompson and William Griffith, and, during its active existence, had the valuable assistance of P. W. Shaefer and J. A. Price, who were removed by death. The reputation of all of these gentlemen is such as to give any conclusions arrived at by them the full force of authority.

After estimating the proportions of the total coal mined that was wasted on the dumps in a number of the leading collieries, which varied from 19·7 per cent. to 74 per cent., they say: "Taking into consideration that the percentage

of coal now sent to the dirt bank is much less than formerly, and the annual production greatly increased, it perhaps would not be unfair to estimate that, since the commencement of mining, the coal and coal dirt sent to the culm banks has been 35 per cent. of the total production, say, 315,700,000 tons."

Mr. William Griffith, under date of April 20, 1892, contributed an article to the *Colliery Engineer and Metal Miner*, in which he estimated, on a basis of 20 per cent. waste, that the amount of clean coal that went to the culm bank in the Scranton district alone, up to and including the year 1891, was 21,975,444 tons.

The estimated total production of this district for the year 1891 was 6,193,390 tons. The output for 1895 amounted, in round numbers, to about 7,000,000 tons. If 20 per cent. of this goes to the culm bank, there is a stream of energy annually flowing to that repository of 1,400,000 tons.

Emery estimates 14·4 tons of coal per annual horse-power, for 365 days of 20 hours each for simple, high-speed, non-condensing engines.[1]

If we assume that the fuel value of this coal, when recovered, is but 78 per cent. of that of the best freshly mined egg, stove and chestnut, this 14·4 tons becomes 18·5 tons,[2] and the 1,400,000 tons now annually going to the culm heap represent a stream of energy equivalent to 75,672 horse-power. This is nearly equal to the maximum estimated capacity of the great Niagara tunnel. But in addition to this as yet practically unutilized flow of energy, there is that vast amount already stored up in the culm banks during the years previous to 1892, estimated at nearly 22,000,000 tons (see *ante*), which, on the same basis, is equivalent to over 1,100,000 horse-power years—the storage of which, in one sense at least, has already been paid for. This annually increasing flow of energy may not inaptly be called the Falls of Scranton, which, unlike the Falls of Niagara, have

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[1] Emery, on "Cost of Steam Power," *Trans. Am. Inst. El. Engineers*, Vol. X.

[2] Wm. McClave, in paper before Anthracite Coal Operators' Association, Philadelphia, Jan. 9, 1895.

not, as they passed by, dissipated their energy, but which, in succeeding years, have stored it up in an available form for utilization at our pleasure.

Some of the industrial establishments at Scranton obtain their culm from their own mines. One of the largest of these is the Lackawanna Iron and Steel Company. This company charges itself a nominal sum of 10 cents per ton for the culm it uses, and it is shoveled into the furnaces just as it comes from the breaker.

The Scranton Illuminating, Heat and Power Company owned a culm pile which was in the way of the Central Railroad of New Jersey. The railroad company was glad to remove the culm, and entered into a contract to supply an equivalent amount as wanted. This they have been doing for years, delivering the culm for nothing at the doors of the electric lighting station.

The Suburban Electric Light Company also owns a culm pile, at the base of which its station is built. Allied interests are engaged in preparing this culm for market. The refuse is carried by a conveyor into the boiler house of the lighting station at small cost.

Parties in and around Scranton have offered me culm, in the bank, in practically unlimited quantities, at from 10 to 15 cents per long ton.

It costs about as much more to properly size it so that it may be said to cost, on board the cars, at the breaker, from 25 to 30 cents per ton.

When culm is spoken of in the culm bank it refers to all of the material, both large and small; but when it is spoken of in the boiler house, it means simply the refuse, including dust and finer coal after the larger sizes have been separated. These larger sizes, including buckwheat and pea coal, command higher prices.

The refuse—strictly speaking, culm—is the fuel preferred by the manufacturers in Scranton, except where the haulage costs too much, when bird's-eye, buckwheat, or even pea coal are preferred; but all of the steam raised in this district is raised by the combustion of the products from the culm bank, and by far the most of it from the refuse or true culm.

Mr. William McClave, in comparing the fuel values of different fuels, rating egg, stove and chestnut coals of good quality at 100, places No. 1 culm at 78 and No. 2 culm at 70 per cent. By No. 1 culm is meant a mixture containing anthracite dust with Nos. 1, 2 and 3 buckwheat, and by No. 2 culm a mixture of dust with Nos. 2 and 3 buckwheat. According to his figures it would require 28·2 per cent. addition to No. 1 culm and 42·9 per cent. addition to No. 2 to make them equivalent in value to good quality egg or stove coal. By increasing the grate areas of the boilers, the boiler capacities, even with these low-grade fuels, need not be materially increased.

Sir William Thomson (now Lord Kelvin) enunciated the law for the most economical size of conductors for the transmission of electrical energy, that "the interest on the investment in copper should just equal the cost of the energy lost in transmission." This is known among electricians as "Thomson's law," but it has a very much wider application than that to electrical conductors. It is merely a specialization of the old saying that one must not spend more for economy than the economy amounts to, and is an economic law, applicable to all the affairs of life.

Applied to steam power, we see its application in this: If fuel be very expensive, we can afford to make a large investment in the way of improved boilers and engines, because by their use the saving in fuel may more than counterbalance the increased interest on the more expensive plant. The same plant which would be economical where fuel were dear would not be economical where fuel were exceedingly cheap, simply because of the fact that the saving of fuel effected by the expensive plant would not offset the increased interest charges on the more expensive plant. It is not necessary to follow this line of reasoning through all of its applications to the cost of power, but it leads to the conclusion, which is well verified by experience, and now recognized by our most advanced engineers, that where fuel is cheap it does not pay to go to extra expense to save fuel, viz.: it does not pay to go into extra refinements in steam engineering, because they cost more than they save.

Considering the question of original investment, therefore, simply from the fuel standpoint, it is apparent that the cheaper the fuel the less we can afford to pay for its saving. This means cheaper boilers and cheaper engines —less original investment and less fixed charges.

It is, however, only those favorably located, as regards the culm, who find it economical to use the cheaper grades. Where the fuel must be transmitted for a considerable distance by railroad, or even very short distances by wagon, it becomes more economical to use a better grade—such as No. 1 buckwheat, or larger—the simple transportation expenses being the controlling element as to which grade of fuel will be the most economical. It not infrequently happens, therefore, even in Scranton, which is as favorably located with regard to the culm piles as any city in the country, that the fuel costs the steam producers 50 to 75 cents, delivered in the boiler-house.

The only preparation which these refuse heaps require for their utilization for steam purposes is a proper sizing, and this is cheaply effected by passing the material over screens which separate it into the following: Pea coal passed through $\frac{7}{8}$-inch mesh and over $\frac{9}{16}$, occasionally $\frac{5}{8}$-inch; buckwheat, through $\frac{9}{16}$ or $\frac{5}{8}$-inch, and over $\frac{3}{8}$-inch; No. 2 buckwheat (rice, bird's-eye), through $\frac{3}{8}$-inch and over $\frac{3}{16}$-inch, occasionally $\frac{1}{4}$-inch; No. 3 buckwheat (barley), through $\frac{3}{16}$, and over $\frac{3}{32}$ or $\frac{1}{16}$-inch; bird's-eye, through $\frac{5}{16}$-inch, and over $\frac{1}{8}$.

Until the production of a suitable grate-bar was an accomplished fact, the fineness of the fuel was the main limiting quality in its use for steam production; but with the introduction of the rocking and dumping grate, of which the McClave is the best known and a type of its class, and the introduction of the blast in a sealed ash-pit, size has become far less controlling than uniformity of size; so that now mixtures containing nothing larger than No. 3 buckwheat, and extending down to as fine as dust, are successfully used.

With the finer materials there is, of course, even with these improved grate-bars, considerable loss in unconsumed

carbon in the ash pit; but this is far less than when unsized material, varying from, say, stove or egg down to dust is used; for in this case, when the smaller sizes have been entirely consumed, rendering it necessary on this account to dump the grate, the larger sizes have been but partially consumed, and go into the ash pit. In one case coming under the observation of the speaker, where unsized material was used, the ash pit contents consisted of from 30 to 40 per cent. of unconsumed carbon, and the economic results were even less favorable than they would have been had the finest sizes of culm, or the refuse after sizing, been employed.

It is almost the universal custom in the anthracite region, where culm is employed, to use a forced draught beneath the grate-bars. This is usually produced by means of a steam jet. The strength of the blast necessary for the most rapid combustion of the fuel is, however, such as to render it necessary to use the culm wet, otherwise the finer particles or dust would be carried bodily up the stack. The action of the steam, however, is beneficial in two ways. In the first place, it prevents the formation of clinker, or, rather, results in the formation of a clinker more friable—and hence more manageable—than would otherwise be the case; and, in the second place, it serves to make the fire-box a water-gas generator.

With the use of fine coal, however, comes the necessity of thinner fires and more frequent stoking, so that, with hand-firing, the proportion of the time when the fire doors are open is large, and this constitutes one of the chief disadvantages in the use of culm for steam-raising purposes.

Automatic stokers in abundance have been suggested and tried, in the hope of avoiding this difficulty, but until we can devise an automatic stoker which also has intelligence, it is doubtful whether this means will be fully effective.

There is one automatic stoker, however, that deserves especial mention. It is what is known as the Coxe automatic stoker, and is the result of a very careful study of the problem by the late Mr. Eckley B. Coxe and his assistants, at Drifton. (A picture of this stoker was thrown on

the screen.) For a description of it I am indebted to an excellent article by Mr. John R. Wagner, in *Cassier's Magazine* for November last, from which the illustration is taken. It consists essentially of a traveling hearth, which is fed continuously at one end and which discharges the ashes at the other.

Provision is made so that in the different stages of its progress, from charging to discharging end, the fuel is subjected to just such pressures of blast as are conducive to the best results. To effect this, the ash pit is divided into a series of chambers closed at the top only by the traveling grate. By the construction of the latter any material leakage from one of these chambers to the other is prevented, so that the pressures in each may be different. Mr. Wagner states that if, in the first chamber, the water-gauge pressure is 1 inch, the pressure in the next would be about $\frac{5}{8}$, in the next $\frac{3}{8}$, and in the next $\frac{1}{8}$ inch.

Furthermore, in order to regulate exactly the pressure of air in each of the compartments, the partitions are provided with registers, by the opening and closing of which the pressure in the air chambers can be varied to suit the conditions. The speed of travel of this grate varies usually between $3\frac{1}{2}$ to 8 feet per hour.

As to the economical results obtained from the last-named device, I have no figures, but with the confessedly imperfect methods of hand-firing, I find that a horse-power can be produced from culm for 365 days of 24 hours each, under favorable conditions, at Scranton, for about $22, and for a year of 313 days of 10 hours each for from $13 to $14.

Such, briefly, is the state of the art to-day in the utilization of anthracite culm piles for the production of power; but we are entering upon a new era which bids fair to throw even these admirable results into the shade.

Every handler of crude products finds that it is advantageous, to a greater or less extent, to prepare his product for market. The coal miner, especially the anthracite coal miner, finds that, by sizing his coal, it is more marketable than when he does not; hence, hard coal can be bought in sizes to suit the customer. When a waste product seeks a

market, it must be in such a shape as to commend itself to the public, or it will be rejected. It has already been shown that the culm yields better results when separated into individual sizes than when used without this separation; but a further preparation, if the cost be not too great, would render it still more valuable.

Metallurgists have long realized that a gaseous fuel is the ideal, and modern science has demonstrated that materials so poor in combustible matter as to be unutilizable directly for the generation of steam, may be converted into gas, and in this form constitute a most concentrated and valuable fuel. The most noteworthy early advance in this line was the conversion of bituminous matters into generator gases, very poor in intrinsic fuel qualities, but which, by the utilization of the regenerative principle, gave rise to a steel process—the Siemens-Martin open hearth steel process—which depends for its success upon high temperatures, hitherto not possible with the best of fuels.

Producer gases of this kind, however, were incapable of transmission to any considerable distances because of the large percentages of condensable products which they contained, and *had* to be used hot. They were not, therefore, commercial fuel gases.

The water gases produced from coke, anthracite and other non-bituminous fuels, of which the Lowe and Strong processes were among the pioneers, introduced a new era of fuel gas manufacture, because they could be produced cheaply and transmitted without condensation.

The general outline of the water gas manufacture is briefly this: a jet of steam is passed up through an incandescent bed of anthracite or coke. The steam is decomposed by the incandescent carbon, the oxygen of the steam going to the carbon, forming carbonic oxide (a combustible gas), and the hydrogen being set free. This process in a short time reduces the fire to such an extent that it must be blown up with an air jet before gas can again be produced, so that the process is an intermittent one. It, however, gives a gas of great calorific power at little cost, and this, when purified and enriched, is largely used as an illuminating gas in many

of our cities, Philadelphia being among those, I am told, which use gas of this kind.

For fuel purposes, however, it is necessary that the gas be even cheaper than this water gas, unrefined and unenriched, and, as a further requisite for its successful manufacture, it is necessary that the process should be a continuous and not an intermittent one.

To Mr. J. Emerson Dowson, of England, is usually given the credit of having first met this want by combining the steam and air blast so as to make the process a continuous one. The resulting gas, though a much poorer one than that resulting from the usual water gas processes, is still cheaper per unit of calorific power, and strong enough for gas engine use. Many others have followed in the steps of Dowson, among whom may be named Lesscauchez and others, but this class of fuel gas is generally known as Dowson gas, and the best known and most used producer is still Dowson's.

The process is simply this: The non-bituminous fuel—either anthracite or coke—is burned in a furnace with blast produced by a steam injector properly regulated so as to produce as little carbonic acid as possible. Dowson prefers to superheat his steam, but uses his air at the atmospheric temperature. To superheat his steam he requires a small auxiliary furnace, but some others do without the superheating (and, consequently, the auxiliary boiler) by relying upon the evaporation of water introduced into the ash pit for the moisture to produce the water gas.

Gases manufactured by any of these continuous processes are necessarily admixed with all of the nitrogen of the air, but the average Dowson gas, notwithstanding this dilution, has a fuel value of about one-quarter of that of ordinary 16 candle-power illuminating gas. One ton of good anthracite coal will produce from 150,000 to 160,000 cubic feet of this gas.

Where anthracite costs $4.50 per ton, Dowson gas costs about 6 cents per 1,000 cubic feet to manufacture.

It is not necessary, however, that we use the best of fuel; for, so long as it is capable of supporting combustion, it is adaptable to the manufacture of Dowson gas, a fair analysis

of which, at 32° F. and 14·22 pounds pressure, is about as follows:

	Per Cent.
CO_2	3·40
O	0·9
H	16·47
CO	27·50
N	51·73
	100·00

When we consider that in the above assumed figures all other costs than fuel amount to about 3 cents per 1,000 cubic feet of gas produced, the possibilities with cheap fuel, such as the culm banks afford, suggest themselves at once.

When we also consider the facility of transmission afforded by a prepared gaseous fuel of such concentration as this, and the economies attending its use as compared with that of solid fuel, the further suggestion obtrudes itself that the conversion of the culm into gas at the culm piles, and its transmission in this form to the point of consumption, would be the proper method to pursue.

But let us compare the cost at various steps. Mr. Dowson estimates the cost of gas producers on a fairly large scale at about $11 per horse-power. I presume that this includes his own services, for I am sure that they can be built for less than that in this country; but even at this cost they are cheaper to install than boilers.

Now as to transmission. We know that those unfavorably situated as regards the culm piles, even in Scranton, cannot advantageously use the cheaper grades of culm by reason of the haulage charges. It has been suggested that the culm be burned under boilers at the banks and its energy transmitted electrically; but many of my audience will be surprised to learn, perhaps, that electricity is not our cheapest method of transmitting energy. We can economically transmit coal by railroad very much further than we can the equivalent energy by electrical means, and yet we cannot transmit this culm more than a short distance, even in this way, and have it an economical product when delivered.

As illustrating the relative economies of gaseous and electrical transmissions, the late Mr. Denny Lane, an English gas engineer of prominence, once stated that, with ordinary 16 candle-power gas, 3,000 horse-power could be sent a distance of 1 mile for an expenditure of 1 horse-power—an economy of distribution far exceeding that possessed by any other system, being only $\frac{1}{30}$ per cent. of the power conveyed.

With respect to the cost of mains, he says, taking the cost of conductors laid on the low-pressure culvert system at £5,500 per mile for the conveyance of 1,080 ampères, and assuming an electromotive force of 110 volts, the power would be 158 horse-power. It would, therefore, require, he says, two pairs of these conductors to convey 300 horse-power, whilst a 6-inch main, with ordinary gas, would convey sufficient gas for that power at 4 inches pressure, and at 16 inches pressure would deliver as much as four pairs of such conductors. The 6-inch main, he says further, would cost £500 per mile, while two pairs of low-pressure conductors would cost £11,000, and four pairs would involve an expenditure of £22,000 per mile.

The lecturer has found, by calculation, that to transmit this power to the distance named, at 220 volts, the metal in the pipes would cost considerably less than the metal in the conductors. Contrast this with electrical transmission, in which 10 per cent., or 300 horse-power, would be an allowable loss, and we see how the gas transmission has the advantage over the electrical.

I also find that a 6-inch pipe will deliver 6,000 cubic feet of illuminating gas per hour at a distance of 10,500 feet under 4 inches of water pressure. If this be 16 candle-power gas, and be used in a gas engine, allowing 25 cubic feet per horse-power hour, this quantity represents 240 horse-power.

Cast-iron pipe, 6 inches in diameter, having a thickness of ½ inch, weighs 31·9 pounds per foot. The total weight of this 2 miles (nearly) of pipe will, therefore, be 334,950 pounds. This would be equivalent in conductivity to about 41,869 pounds of copper equally distributed over the same

distance. But 4 miles of copper, weighing 41,869 pounds, would be equivalent to about four No. 000 B. & S. wires, which would have a resistance for the 4 miles of 0·325 ohm. If the charging current were transmitted at 220 volts, there would be required a current of 848 ampères; but a wire having a resistance of ·325 ohm will only deliver under a pressure of 220 volts; 220 ÷ ·325 = 677 ampères; there would, therefore, be required five No. 000 B. & S. wires to deliver this energy, and the weight of this would be 53,540 pounds.

If the distribution took place at 1,000 volts, the ampères required would be approximately 180. To deliver this at the same distance with a loss of 10 per cent. would require 6,264 pounds of copper, and to deliver it at 1 per cent. loss would require 62,642 pounds, which would cost far more than the pipe, and still give less efficient transmission.

When the fuel is delivered in this form, it is adaptable to all of the uses to which fuel is ever applied. It can be burned under boilers for the raising of steam for power or heating purposes, or it can be applied to domestic uses, or it may be used directly to advantage in gas engines. In no case need there be any stand-by losses, such as are inevitable with solid fuels; for when the fires are wanted it is only necessary to turn on the gas, and when they are no longer needed it may be turned off, and there are no ashes or coal to be handled.

For power purposes, a somewhat extensive investigation of the question has satisfied me that, if we can procure cheap gaseous fuel, the gas engine is the proper thing to use, especially in situations such as are found in our electric lighting stations and elsewhere, where the load is variable between wide limits.

In such situations a portion of the boiler plant must lie idle during the hours of light load, and it has been estimated by very competent authorities that the consumption of coal of the idle boilers amounts to 10 per cent. of the total consumption of all the boilers.

With the gas generator the stand-by losses are so small as to be negligible in comparison, so that a direct gain in economy is here attained.

I believe that all of the English gas engine manufacturers will guarantee their engines, even in comparatively small sizes, to produce a brake-horse-power-hour, when using Dowson gas, on $1\frac{1}{4}$ pounds of anthracite coal or less. It is seldom that our largest compound condensing steam engines are found to give equally good results.

In view of these facts, there are many, myself included, who believe that the problem of utilizing the culm accumulations is to be solved by the conversion of this culm into a cheap fuel gas at the banks, and its transmission thence in pipes to the point of consumption, or to centers of distribution by other more convenient means.

I believe, although I have not attacked this problem from the numerical side, that it would be economical to pipe this artificial gas to Philadelphia from the nearer coal fields. I know, however, that it would be more economical for your electric lighting and power companies to convert their fuel into gas on the water front, and distribute it thence in pipes to gas engines favorably located as to distribution, than to cart their coal to these centers, pay rent or interest on the investments required for boiler and coal storage room, and other attendant expenses.

The only question in my mind is whether it would be cheaper to manufacture the gas at the culm pile and transmit it in pipes to the water front, or to transmit the better grades of fuel in the solid form to the latter point, and there convert it into a gaseous fuel.

We have seen that in the Dowson gas about half of it is nitrogen, which is inert and acts as a diluent to the fuel value of the gas. If there were any way of absorbing this, it would be a great boon to the fuel gas manufacturer, since it would enable him to send to market a still more concentrated fuel. But nitrogen is singularly inert and we know of no ready absorbant of it. The nitrogen compounds, such as the cyanides and ammonia salts, are, however, exceedingly valuable and in almost unlimited demand. If it were possible to chemically combine this nitrogen of the fuel gas, therefore, we would "kill two birds with one stone" —enrich our gas by the removal of a diluting element, and have as a by-product a commercial product.

Many attempts have been made to accomplish this end, none of them, however, as yet reaching the commercial stage.

I have very recently had the opportunity of visiting the latest experimental plant designed for this purpose—that of the Fogarty Gas and Chemical Company.

According to Mr. Fogarty's theory, nitrogen, when heated to 1,900° to 2,000° F. in the presence of nascent carbon and an alkali, forms a cyanide of that alkali. The general method of operation is to produce a carbonic oxide combustion of the fuel by means of an air-blast sufficiently highly heated to produce the temperature required, and also to decompose a rich hydrocarbon gas supplied above the zone of combustion. The cracking of the hydrocarbon results in the liberation of carbon, which, in its nascent state, unites with the nitrogen to form cyanogen, and this, in the presence of the alkali, is at once fixed as an alkaline cyanide.

It is claimed that if but 3 per cent. of the nitrogen can thus be fixed, the resulting products will be more valuable than the gas, pay the entire expense of its manufacture, and yield a nice profit in addition.

The success of this process on a commercial scale has not yet been demonstrated, but a plant of considerable size, intended to demonstrate this, is now nearly ready for test. Should it prove successful, as we must all hope it will, it will be but another striking illustration of the utilization of waste products.

A process, such as this, which will give us a commercial product from an undesirable constituent of our fuel gas, will cheapen the latter and add a large increment to the value of that other hitherto waste product, the culm pile.

As the conversion of coal into gas for fuel purposes is bound to replace its use in the cruder condition, so will any such additional process, as that which renders possible the commercial fixation of the nitrogen of the fuel gas, supplant processes which do not accomplish this end. That which is fittest will survive.

ENGINEERING AS EXHIBITED ON THE GREAT LAKES.*

By John Birkinbine,
Member of the Institute, Past President Am. I. M. E., etc.

[*Concluded from vol. cxli, p. 447.*]

LAKE HURON.

Lake Huron has abundant evidences of engineering ability in the railroads and industries of Detroit and Port Huron, the lumber mills and salt wells of Michigan, etc., while the Government work of improving the connections with other lakes offers much of interest. However, the unique feature is the *St. Clair Tunnel*, extending from Port Huron, Mich., under the St. Clair River, to Sarnia, Ont., and connecting the Grand Trunk Railway system of Canada with the Chicago and Grand Trunk Railway, completed at a cost of $2,700,000. The tunnel proper is a continuous metal tube, 19 feet 10 inches in diameter, and 6,025 feet, or more than a mile long. The length of the approaches, in addition to the tunnel proper, is 5,603 feet. As one passes through the Egyptian darkness of this great engineering work seated comfortably on a car, and realizes that in the waters above him float annually a greater tonnage than enters the port of Liverpool, the achievements of the engineer are emphasized.

LAKE ERIE.

Lake Erie, the shallowest of the Great Lakes, has, in its cities of Buffalo, Dunkirk, Erie, Cleveland, Ashtabula, Loraine, Sandusky and Toledo, much of interest in their harbor improvements, public works, industries, etc.; but none are more instructive than the ship-building establishments, and the great iron ore receiving docks, which have carried in stock at one time nearly 5,000,000 gross tons of iron ore. At these docks buckets of ore are raised from the holds of vessels and delivered 300 feet distant, on stock piles or on cars, at a cost of less than 1 cent per ton.

* A lecture delivered before the Franklin Institute, December 6, 1895. The lecture was liberally illustrated by a large number of lantern slides.

THE LAKE MARINE.

A feature of the improvement in the lake marine is emphasized by constantly declining freight rates; thus, iron ore, which commanded $1.75 in 1887, was carried eastward in 1894 for 70 cents per ton; coal was transported in the opposite direction for 90 cents in 1887, and 40 cents per ton in 1894; the rate on flour—29 cents per barrel in 1887—was reduced to 24 cents in 1894, while the grain rate in the same time fell from 7 cents to 2½ cents per bushel, and the lumber rate was reduced from $4 to $1.90 per 1,000 feet. The minimum prices show the possibilities, for freights were exceptionally low in 1894 and in the first half of 1895; but notwithstanding later advances, there has been a decided cheapening as larger and faster vessels and better terminal facilities were supplied.

It must be remembered that the statements concerning traffic through the St. Mary's Canal merely cover that originating on or destined for Lake Superior, the commerce of the entire lake system being two and one-half or three times as great; but the immense quantities which are handled through the locks represent but about seven months' business, for the severity of the climate closes navigation on the upper lakes from the end of November to the first of May. It is doubtful whether this period will be lengthened, although suggestions have been made to keep a channel open by powerful boats, similar to those used to transport railroad trains across the Straits of Mackinac.

The *St. Marie*, the newest addition to the fleet of ice fighters, has a length of 300 feet and weighs about 3,000 tons. It is equipped with engines of 4,500 horse-power, and has a 14-foot propeller in each end. This boat has traveled through ice 2 feet thick, at a speed of 8 miles per hour, and has crushed through immense floes.

The United States Commissioner of Navigation, on June 30, 1895, reported 1,755 steam, 1,100 sail and 487 unrigged United States vessels, with a tonnage exceeding 1,250,000, enrolled in the lake customs district. He also shows that during the year there were 22 large merchant vessels, averaging about 2,500 tons each, built in the United States, of which

11 were constructed on the lakes, 10 on the Atlantic and Gulf, and 1 on the Pacific coast.

Thirty vessels, aggregating a tonnage of 100,000 tons, are under construction in the shipyards on the lakes. Among the later contracts is one made at Detroit for three car-transfer boats for the Trans-Siberian Railroad, to be used on Lake Baikal, in central Siberia.

Passenger Steamships.—Within late years, the character of the lake marine has been greatly improved by larger vessels, many constructed of metal and supplied with machinery of the highest economy. Being used exclusively for passenger service, the new steamships *Northwest* and *Northland* are considered queens of the lake marine; but some of the vessels constructed for the iron ore trade are equally good specimens of marine engineering, and of equal size. The two passenger boats above mentioned (the only water-tight compartment steel vessels now on the lakes with quadruple expansion engines and twin screws) are 400 feet long, and have a displacement of 4,500 tons. The two engines on each vessel can develop 7,000 horse-power, and are supplied with steam by twenty-eight Belleville boilers. This equipment drives these boats from Buffalo to Duluth, 1,000 miles, in sixty-five hours, making four or five stops. When the shallow places in the rivers connecting the lakes are deepened, and the new locks are in use, it is expected that the time of travel can be materially reduced.

Freight Steamships.—One of the largest freight vessels now plying on the lakes is the *Victory*, a steamer which has the following dimensions: 380 feet keel, 400 feet over all, 48 feet moulded beam, and 28 feet moulded depth. The depth of her water bottom is 66 inches. The best indication of her cargo capacity is her first load, which was 3,689 gross or 4,132 net tons of iron ore, taken from Two Harbors to Cleveland, on a draft of 14 feet 3 inches. Clear open deck facilitates the handling of cargo through numerous hatches.

Other vessels of as great size are now being constructed, although there is a wide difference of opinion among navigators as to the advantage of these in the

present tortuous and shallow condition of some of the channels and rivers. The *Victory*, although a new vessel, has made some remarkable records for quick dispatch; its cargo of coal bound west was loaded in ten hours, at the rate of 400 tons per hour, and unloaded at the head of the lake in fifteen hours. It was loaded at Two Harbors, Minn., with iron ore in five hours, the rate of loading being 800 tons per hour, the ore being unloaded and placed on cars at Ashtabula at the rate of 560 tons per hour. As in unloading, all the material must be shoveled into buckets, this record is remarkable. When engaged solely in the iron ore traffic, bringing only east-bound cargoes, this vessel receives its load of about 4,000 tons of ore at Two Harbors, Minn., travels to Cleveland or Ashtabula, discharges its cargo, and returns light, ready for another cargo, within seven days; but if a load of coal is taken westward, the time of taking on and discharging this cargo and the slower progress made increases the round trip to ten days.

The *Zenith City*, a sister ship to the *Victory*, but somewhat larger, is constructed throughout of steel, the channel system of construction being used, instead of plates and angles. Her length is 405 feet, beam 48 feet, depth of hold 28 feet. The vessel is driven by triple expansion vertical engines, 22-inch, 38-inch and 63-inch cylinders, stroke 40 inches, and equipped with water tube boilers. The vessel cost $225,000, and carried one cargo of 138,000 bushels of wheat.

The *Rappahannock*, a wooden freight screw steamer, the *Marine Review* states, measured: length over all, 335 feet; beam, 43 feet; depth, 26 feet; displacement at 15 feet draft, 2500·6 tons. The engines are triple expansion, 20, 32 and 54 inches diameter by 42 inches stroke. The boilers, two in number, are 12 feet 3 inches diameter by 12 feet long, for a working pressure of 160 pounds. Each boiler has two 42-inch furnaces and 314 tubes of 2½ inches diameter. The total grate area is 84 square feet, and total heating surface 3,786 square feet. With a cargo of 80,000 bushels of wheat, or 2,400 net tons, from Duluth, on a draft of 14 feet 4½ inches, a test was made under regular working conditions. The coal used was ordinary run of mine, costing about $2

a ton at Lake Erie ports. The boiler test extended over ten hours. For four hours and fifteen minutes indicator cards were taken from the engines every fifteen minutes, and also readings of meter, temperature, steam, vacuum and revolutions; during the balance of test every thirty minutes. The fuel and water consumption per indicated horse-power are, therefore, referred to the time during which observations were made most frequently. The moisture in coal was found by placing a carefully weighed quantity over the boilers and allowing it to dry for about sixteen hours.

The record showed:

Speed per hour, miles per log, mean	12·75
Revolutions per minute, mean	85·08
Steam pressure at throttle, mean	153·5
Vacuum, mean	21 inches
Indicated horse-power, mean	1,167·34
Total coal burned, pounds	20,255·
Per cent. of ashes	8·59
Per cent. of moisture in coal	4·
Water evaporated per pound dry coal, pounds	8·04
Water evaporated per pound combustible, pounds	8·76
Dry coal per hour, pounds	1,944·48
Feed water to boilers (during engine test), pounds	70,103·75
Coal per indicated horse-power per hour, pounds	1·75
Combustible per indicated horse-power per hour, pounds	1·4
Water per indicated horse-power per hour, pounds	14·07
Water per indicated horse-power per hour, pounds (auxiliaries deducted)	13·07
Indicated horse-power per square foot of grate	13·89
Coal per square foot of grate per hour, pounds	24·11
Ton-miles per hour	30,600·
Coal per ton-mile, ounces	1·01
Miles per ton cargo for 1 cent fuel	157·2

This is equivalent to carrying 1 ton 1 mile for $\frac{63}{100}$ of a mill, at the rate of 12·75 miles per hour.

An interesting point is a comparison of the efficiencies of the plant as between Lake Erie and Lake Superior. The observed temperature of the water of Lake Erie was 73·5° to 75° F.; consequently it was almost impossible to obtain a better vacuum without the use of excessive quantities of injection water. With the same or even a less quantity of

injection on Lake Superior, where the water temperature was 45°, it was possible to obtain 24 inches vacuum. The increase in indicated horse-power would be easily 125, which would not cost 1 cent, and the apparent fuel and water consumption per indicated horse-power would be reduced nearly 11 per cent.

Whalebacks.—The advances in shipbuilding on the Great Lakes has been referred to, but such reference would be incomplete without mention of the special constructions, the "whalebacks" and the steel canal-boats. The shallow waters in the rivers caused vessels to be constructed of lengths and breadths disproportionate to depths, so as to have large carrying capacity, and the number of hatches to facilitate prompt loading and unloading had a tendency to weaken the structures. An outgrowth of the lake marine to meet the existing conditions was the "whaleback," which has been sufficiently satisfactory to encourage the construction of a fleet of forty of these oddities.

The "whaleback," although familiar to those who traverse the Great Lakes, dates back but seven years, in which interval fifteen steamers, with an aggregate carrying capacity of 36,000 gross tons, and twenty-six consorts, capable of carrying 60,000 gross tons, have been constructed. This tonnage is based upon present available draught of 14 feet 6 inches; when this draught is increased to 18 feet, the existing fleet of whalebacks can carry 125,000 gross tons. Four more of these vessels, each of about 5,000 tons, are now under construction. One was built in England, and one on the Pacific Coast; and it is claimed that but one of these vessels has been lost, for which gross carelessness is charged.

Having so little superstructure, the whalebacks drift less than the ordinary vessel, and the rounded deck and stem assist their easy riding in a heavy sea. The builders estimate that a whaleback will carry 20 per cent. more cargo than other vessels with the same amount of dead weight, framing and plating being equal. During the season of 1895, one of the steam whalebacks, towing two consorts, made nineteen round trips of an average of 1,720

miles each, and delivered fifty-seven east-bound cargoes, aggregating 131,785 gross tons, besides carrying a considerable amount of west-bound freight; the consumption of coal for the season was 5,403 net tons. Another one of these steam whalebacks, with two, and sometimes three, consorts, made seventeen round trips, delivering fifty-four east-bound cargoes, amounting to 126,389 gross tons, on a consumption of 4,585 net tons of coal. The engines on these steamers are triple-expansion, of 1,000 horse-power, supplied by Scotch boilers.

The above figures show that this work was performed with a consumption of $\frac{4}{10}$ ounce of coal per ton-mile for the round trip, which, equated for the east-bound trip only, would show $\frac{1}{4}$ ounce per ton-mile. See *Fig. 4*.

Steel Canal-Boats.—The steel canal-boats are a late innovation, intended to convey heavy freight through the lakes and the Erie Canal. They each carry about 200 tons and travel in fleets, one boat with engine pulling a number of consorts.

Another interesting feature of ship-building on the lakes is the practice of launching vessels sideways.

Improvements for Navigation.—The Government has expended large amounts in improving the waterways connecting the Great Lakes, but liberal appropriations will be required to place them in condition to pass vessels drawing 20 feet of water, for to-day adverse winds may prevent vessels, when loaded so as to be within the limit of the present canal (16 feet), passing shoals; in fact, few risk over 14 feet 6 inches draught.

Those engaged in commerce on the lakes jealously watch every increase or decrease in depth, and considerable interest has followed the proposal to withdraw from the lower end of Lake Michigan from 5,000 cubic feet at a minimum to 10,000 cubic feet at a maximum per second through the Chicago Drainage Canal. Estimates are made that the average reduction of the level of Lake Michigan from this cause will be between 3 and 4 inches, reducing the carrying capacity of the lake fleet, and consequently its earnings, over $500,000 annually.

With 90,000 cubic feet per second pouring from Lake Superior into the great reservoirs of Lakes Huron and Michigan, the diversion of the amounts above-named would at first sight seem insufficient to affect the level, without considering the streams naturally tributary to these lakes.

A late prophecy comes from across the ocean that the deepening of the waterways of the great lake system will force new ports to be formed, basing this assumption upon the shallow waters in the harbors and rivers of the important lake cities, to deepen which will jeopardize the foundations of warehouses, etc., constructed at or near the dock line. Such an emergency may face a few localities, but the energy which has developed the enormous lake traffic will find means for keeping it.

Congressional action is being asked to secure an investigation of the possibility of raising the water level of Lake Erie by a dam near Buffalo, which will not only deepen all harbors on this lake, but improve navigation on the Detroit River and possibly on St. Clair Lake and River.

The great iron and steel industry, which has achieved renown for its output and economies of production, the shops which turn out vessels and machinery magnificent in design and proportion, the varied manufactories, the unique bridge work, the municipal improvements, etc., have all been passed by in this imperfect chronicle.

One might continue a journey from Lake Erie through the Welland Canal, which passes moderate draught vessels across the Canadian peninsula to Lake Ontario, a descent of 325 feet, then through Lake Ontario and down the canals of the St. Lawrence River, finding continually evidences of engineering skill; but these must be passed by, to close an incomplete *résumé* by calling attention to the water-power, much of which may be, and a very little of which is, harnessed for service, and the possibility of connecting the Great Lakes with the seaboard.

WATER-POWERS.

The shores of Lake Superior and portions of some of the other Great Lakes are not level plains, but for the greater

part rise rapidly, hence there are numerous cascades and waterfalls. One of the most promising of these is the St. Louis River, entering Lake Superior at its westernmost point. Here in 10 miles the river falls 440 feet, and delivers, from a drainage basin of 4,000 square miles, from 1,200 to 2,400 cubic feet of water per second. Thus at the western extremity of the present navigation is a large water-power of 40,000 horse-power awaiting improvement, while at the eastern end is the Falls of Niagara, the partial utilization of which is now looked upon as opening a wide field for the economical development and transmission of electrical power.

The possibility of making some deepwaterway connection between the Great Lakes and the Atlantic Ocean has been discussed for a number of years, and similar projects for uniting the waters of the Mississippi and the Ohio with the Great Lakes have been brought forward. At present the Chicago Drainage Canal is the most advanced step towards securing the latter, although a survey has been made to reach the Mississippi River above St. Paul and Minneapolis from the head of Lake Superior, and a commission is now engaged in discussing canalization schemes for uniting Lake Erie and the Ohio River. Canals to make a more direct connection between Lakes Superior and Michigan, and between Lakes St. Clair and Erie, are also proposed. A project, bold in its conception, is advanced, which, by deepening the summit level of the Welland Canal or by cutting a new canal in the State of New York around Niagara Falls, and by deepening the St. Lawrence Canals, connecting Lake Francis and Lake Champlain by a new canal, and Lake Champlain with the Hudson River by a new canal, is to provide deep-water transportation between the Great Lakes, Montreal and New York. Instead of the numerous locks of small depth, it is proposed to employ locks of 150 feet or more lift, operated by compressed air, the vessels being carried in metallic basins superposed upon immense air cylinders. The attention which is being given all over the world to schemes of canalization and river improvement point to an appreciation of

the value of water transportation; and although it may seem visionary, it is not improbable that the engineer will yet accomplish the desired result of transferring large vessels from the lakes to tide-level. A region which has developed so many surprises could well afford to add this to the list. In fact, an International Deepwaterways Commission is now organized to consider such projects.

Joint Meeting of the Chemical and Electrical Sections, May 26, 1896.

RETURN CIRCUITS OF ELECTRIC RAILWAYS.

By Charles Hewitt.

Electric traction began its rapid progress in the year 1887. The first roads, with the exception of that in Richmond, were mostly suburban lines, or were located in the smaller cities. It was not until the larger cities began to adopt electric traction that the electrolysis of iron pipes began to show itself; not until the summer of 1891 did this trouble take any definite shape.

The Erie Motor Company, Erie, Pa., experienced much trouble with the water pipes in its station; the company also had complaints from the plumbers in town that the service pipes were rapidly being corroded. I made an examination of this plant and others in Pennsylvania, and found a very bad state of affairs. At that time it was not definitely known that the trouble was due to electrolysis; in fact, as most of the trouble was confined to the station, it was supposed that the trouble was due to bad feed-water. I found rail bonding very poor. In some places there were no bonds at all. I also found the positive pole connected to the pipes and track, the negative pole being connected to the trolley wire. At that time a considerable number of roads were connected in this manner. On investigation I found that 40 per cent. of the total output of the station was carried by the pipes, and it was soon very evident to me that the trouble was an electrical one, pure and simple.

In the course of a few months various notes began to be published in the different papers in regard to trouble with water pipes; but it was not until Mr. Farnum, of Boston, read his paper before the American Institute of Electrical Engineers that the trouble was placed before the public in any precise form, although it was well understood by the companies manufacturing railway apparatus for months previous. From that time to the present, much has been written and many suggestions made, and a large amount of data collected, so that at the present time I believe we are in shape to contend fairly with the disease.

In considering this subject it will be well, in the first place, to inquire what causes electrolysis, and why are we troubled by it. Various explanations have been given, and I must confess that at the present time I am not able to answer the question positively. One thing is certain, namely, that it takes place more rapidly in salty earth than in dry sandy soil. Copper return wires in dry sand have remained apparently unaffected for years; whereas, similar wires buried in the soil of Salt Lake City will scarcely last three months. In the case at Erie, previously cited, much of the trouble was in water pipes which were suspended in the air and showed the corrosion on the inside. Whether the corrosion was due to nascent gases or to the decomposition of salts, I am not prepared to state; it seems evident, however, that moisture in some form is necessary to cause the trouble, and I believe that the most destructive element is the nascent oxygen. Our text books, however, say that it takes a pressure of nearly 2 volts (1·47 Gore) to decompose water; whereas, Prof. Jackson has proved conclusively that a mere directive force is all that is necessary to cause electrolysis; and to my knowledge electrolysis has very rapidly taken place under pressure of less than 1 volt.

The electrolytic action is quite characteristic and is very easily distinguished from ordinary corrosion. You will see by the samples here exhibited that there is a decided pitting of the surface of the metal, whereas the corrosion of an ordinary rusted pipe is of a fairly uniform character. This pitting, I presume, is due to the fact that

the metal is not perfectly homogeneous, and that the purer iron is the most readily attacked.

It is somewhat amusing, at the present day, to recall the fact that, in the year 1887, the earth and rail-return were considered as zero resistance; we know, at the present day, that this is so far from the fact, that the rail-return problem is one of quite as great importance as the feeder problem.

Now, why does electrolysis bother us at all? In considering this, we must look upon rails and the pipes as two separate systems of conductors, which, in their normal condition, are slightly insulated from each other by a layer of earth. If, therefore, the track were of zero resistance, or the insulation between the track and the pipes were of infinite resistance, it is very obvious that no current would leave the rails and enter the pipes. Unfortunately, neither of the conditions can be perfectly realized. The actual conditions can be shown more clearly by *Fig. 1*. In this, for

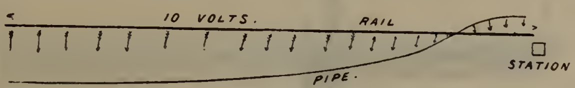

FIG. 1.

simplicity's sake, we will assume a straight road with the station at one end, representing the track by the heavy straight line; we shall assume, also, that, between the far end and the power house, there is a drop of 10 volts. Now, with any such drop in the track, and with a system of piping below the track forming a fair conductor on account of the very mass of the material, it is very evident that some of the current will seek this path, and more or less will be thus diverted in proportion to the drop in the rail.

Referring again to *Fig. 1*, I have endeavored to show the condition of the pipe in reference to that of the track by the curved line. At the outer end it is very evident that the potential difference between the rail and the pipes would be a maximum, assuming, of course, that the trolley wire is positive, and that the current is flowing towards the station. This difference in potential will gradually decrease as we approach the station, until we reach a point where

the drop in the track and the drop in the pipe, together with the resistance between rail and pipe, combine to form a neutral point; from this point out there can be no electrolysis of the pipes (except at local points); but as we approach near to the station, the potential of the pipe begins to rise above that of the track, and it is just here that we may begin to look for trouble.

The electrolytic action takes place only at the anode or positive pole. The region between the station and neutral point we will call the danger area, and our sole concern is to protect the pipes in this region. Now, how shall this be done? It is very obvious at the outset that we must straighten out the curved line in *Fig. 1.* In other words, we must make the pipe negative to the rail at all points.

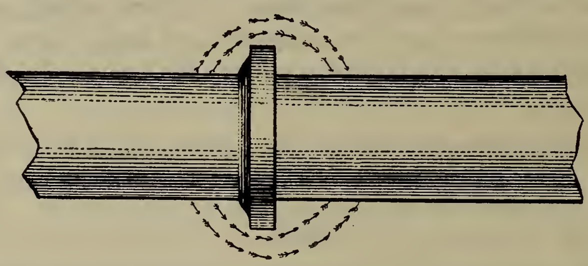

FIG. 2.

So far, I have assumed that no connections have been made between the rail and the pipe. Many engineers have recommended the connecting of the pipes and the rail-return, and I believe there are to-day advocates of this scheme, but, to my mind, the suggestion is utterly preposterous. Why aggravate our trouble by inviting currents into the pipe, when we have sufficient trouble from the currents which enter the pipes uninvited? Ordinary gas and water pipes have not been laid with the view of being utilized as electrical conductors; they become good conductors simply from the very mass of iron of which they are composed. The joints, however, are anything but perfect metallic unions, and although these may transmit small currents with impunity, if we force larger currents through the pipes, we will get a drop at the joint, which will give

us a condition shown in *Fig. 2*, in which the drop in the joint is supposed to be sufficient to overcome the resistance of the earth around the joint and cause some of the current to flow around the outside. This condition, as you will see, will cause a local danger point at one side of the joint. To me it seems just as reprehensible on the part of a railway company to appropriate the pipes of the water and gas companies as an annex to their system, as it would be to appropriate the conductors of another electric company.

The position of the engineer is now very clear, and may be stated as follows: Do not invite current into the pipes, but take care of all that comes in uninvited; in other words, keep pipes and return system as distinct from each other as possible, and make the resistance of the track system as low as possible.

We are now in a position to take up the various devices that have been suggested for overcoming the trouble. Naturally, our first consideration is a perfect rail bond. A 60-pound copper rail has a cross sectional area of 8·3 square inches, which, at the ratio of 7 to 1—which ratio is the one usually given for the conductivity of iron and copper—would be equivalent to a conductor of 1,500,000 circular mills. Since, however, our rails are made of comparatively high-carbon steel, I am inclined to think that the true ratio is nearer 10 to 1, which would make the rail equivalent to a bar of 1,050,000 circular mills copper.

When we realize that there are two rails in each track, and that all the ramifying tracks in a large city like this are connected together, we begin to realize what an immense mass of electrical conductors the tracks present. It would be very injudicious, therefore, and a needless expense to abandon the tracks as conductors.

Mr. J. H. Vail advocates the use of the return feeders to an extent which practically eliminates the track as a conductor, and I believe he has patented a system of track feeders which is the counterpart of the ordinary system of feeders used in lighting and railway work; and he proceeds to figure the drop in the return feeders in the same manner that he would figure the drop in the positive

feeders, eliminating the track from consideration. A system of this kind is needlessly expensive, for reasons which I have already shown. If the track be well bonded there is no necessity for an elaborate system of track feeders. In some of the smaller roads, no track feeders whatsoever are necessary; in the larger roads, such as we have in this city, there are many places where the current density becomes so great that it is advisable to augment the track by the addition of a proper amount of copper; in fact, all track in the city should be protected by a smaller or greater amount of copper, in order to guard against broken bonds, as well as to provide a better conductor.

A modification of the Vail system of track feeders consists in running a copper cable or bar in a trough filled with insulating material and parallel to the track. This conductor should decrease in size as it gets farther away from the station. There is no doubt in my mind of the advisability, in all cases, of protecting the return cable with a moderate amount of insulation. Experience has proved, time and time again, that an unprotected copper conductor laid between the rails is very liable to be reduced to a state of "innocuous desuetude" by the very action it is intended to prevent.

Both of the above-described systems of return feeders will reduce the liability to injury to the pipes, but will not entirely prevent it; in other words, unless the copper is infinite in amount, we will still have a danger area in the vicinity of the power station. Our care, therefore, should be to provide an amount of copper for the return which shall be in accordance with the demands of each individual road; and, in addition, we must provide a means of protecting the pipes within the danger area. The first, and, perhaps to the present day, the best, suggestion which has been made was that presented by Mr. Farnum, in the paper previously cited. This consists in running one or more return feeders to all the pipes which show a potential positive to the track or return cables. This return feeder must have no direct connection with the other return feeders, except at the negative bus bar, and must be of sufficiently

low resistance to bring the potential of the pipes at least down to that of the tracks at each point between the power house and the danger line.

I am well aware that, in many cities, the track bonding is very inferior, and also that the tracks have been bonded to the pipes. Both of these will aggravate the difficulty of reducing the potential of the pipes by the separate return feeders; but if the road be well bonded and no connections have been made between pipe and rail, the matter becomes quite easy of solution. I have been informed by the very highest authority that, of the output of 8,000 ampères in one of our Eastern cities, 5,000 ampères is returned by the pipes. Is it any wonder that the city authorities object? In contrast to this, in three stations in this city, which I have personally tested, I find that, in a station with an output of 3,000 ampères, the maximum returned by the pipes was 50 ampères, or $\frac{1}{60}$ of the total output. In the other two stations the ratio between the output and the main return by the pipes was practically the same, namely, $\frac{1}{60}$ of the total output. You will readily see that we have here a much easier problem to handle.

One of the most recent methods of reducing the potential of the pipe below that of the rail has been suggested by Mr. Harold P. Brown, and has been very widely advertised by magazine articles and otherwise. This plan is to connect the negative lead of one generator to the pipe system in the station, and to run this generator at a greater difference of potential between its leads than between the negative bus bar. Mr. Brown, in a recent article in *Cassier's Magazine*, has claimed, by the use of this system, to have made a reduction in the output of the power station in Newark of 300 horse-power. It seems to me that this plan is radically at fault; for, even taking no account of the difficulties of running a special generator for this purpose, it is self-evident that all the current generated must be returned through the pipes, and, to my mind, it is absolutely wrong to compel a single ampère of current to enter the pipes; our efforts should rather be in the opposite direction. The complications necessary for using the double ground on our

machines, of giving up one machine for this special purpose, or even of installing a separate machine to do this work, will be apparent to every one.

A modification of this plan, however, and which, I believe, has never been publicly advocated, has occurred to me, namely, the application of what might be termed an inverted booster. Assuming that we have a separate set of pipe return feeders, and that in this feeder, before attaching it to the negative bus bar, we place a series dynamo which shall have a current capacity equal to the amount of current returned by the pipes, and a potential only sufficient to overcome the maximum difference of potential between the pipes and the track. This generator will have a tendency, then, to lower the potential of the pipes below that of the negative bus bar, and, being of very low potential, it need only be a very small machine. For instance, in the station above referred to, where the maximum current returned by the pipes was 50 ampères, the maximum difference of potential was also found to be less than 1 volt; if, therefore, we put in a generator of say 100 ampères capacity and 5 volts, we have a machine of only ½ kilowatt, which could readily be run by a 1 horse-power motor. You see how small a machine this plan demands. It would be automatic in its action, inexpensive and easily installed, and I believe would give absolute protection to the pipes. In cases such as those stated above, where the current returned by the pipes is abnormal, it would be necessary to put the rail-return system in proper shape, and then use the booster as a final refinement.

ELECTRICAL SECTION.

Stated Meeting, December 19, 1895.

MR. CARL HERING, President, in the chair.

MECHANICAL CONCEPTIONS OF ELECTRICAL PHENOMENA.

BY PROF. A. E. DOLBEAR,
Tuft's College, Massachusetts.

[*Concluded from vol. cxli, p. 463.*]

So far as we have knowledge to-day, the only factors we have to consider in explaining physical phenomena are: (1) Ordinary matter, such as constitutes the substance of the earth, and the heavenly bodies; (2) the ether, which is omnipresent; and (3) the various forms of motion, which are mutually transformable in matter, and some of which, but not all, are transformable into ether forms. For instance, the translatory motion of a mass of matter can be imparted to another mass by simple impact, but translatory motion cannot be imparted to the ether, and, for that reason, a body moving in it is not subject to friction, and continues to move on with velocity undiminished for an indefinite time; but the vibratory motion which constitutes heat is transformable into wave motion in the ether, and is transmitted away with the speed of light. The kind of motion which is thus transformed is not even a to-and-fro swing of an atom or molecule like the swing of a pendulum bob, but that due to a change of form of the atoms within the molecule, otherwise there could be no such thing as spectrum analysis. Vibratory motion of the matter becomes undulatory motion in the ether. The vibratory motion we call heat; the wave motion we call sometimes radiant energy, sometimes light. Neither of these terms is a good one, but we now have no others.

It is conceded that it is not proper to speak of the wave motion in the ether as *heat*; it is also admitted that the

ether is not heated by the presence of the wave—or, in other words, the temperature of the ether is absolute zero. Matter only can be heated. But the ether waves can heat other matter they may fall on, so there are three steps in the process and two transformations: (1) vibrating matter; (2) waves in the ether; (3) vibration in other matter. Energy has been transferred indirectly. What I want to impress in this is, that when a form of energy in matter is transformed in any manner so as to lose its characteristics, it is not proper to call it by the same name after as before, and this we do in all cases when the transformation is from one kind in matter to another kind in matter. Thus, when a bullet is shot against a target, before it strikes it has what we call mechanical energy, and we measure that in foot-pounds; after it has struck the target, the transformation is into heat, and this has its mechanical equivalent, but is not called mechanical energy, nor are the motions which embody it similar. The mechanical ideas in these phenomena are easy to grasp. They apply to the phenomena of the mechanics of large and small bodies, to sound, to heat and to light, as ordinarily considered, but they have not been applied to electric phenomena, as they evidently should be, unless it be held that such phenomena are not related to ordinary phenomena, as the latter are to one another.

When we would give a complete explanation of the phenomena exhibited by, say, a heated body, we need to inquire as to the antecedents of the manifestation, and also its consequents. Where and how did it get its heat? Where and how did it lose it? When we know every step of those processes, we know all there is to learn about them. Let us undertake the same thing for some electrical phenomena.

First, under what circumstances do electrical phenomena arise?

(1) *Mechanical*, as when two different kinds of matter are subject to friction.

(2) *Thermal*, as when two substances in molecular contact are heated at the junction.

(3) *Magnetic*, as when any conductor is in a changing magnetic field.

(4) *Chemical*, as when a metal is being dissolved in any solution.

(5) *Physiological*, as when a muscle contracts.

Each of these has several varieties, and changes may be rung on combinations of them, as when mechanical and magnetic conditions interact.

(1) In the first case, ordinary mechanical or translational energy is spent as friction, an amount measurable in foot-pounds, and the factors we know, a pressure into a distance. If the surfaces be of the same kind of molecules, the whole energy is spent as heat, and is presently radiated away. If the surfaces are of unlike molecules, the product is a compound one, part heat, part electrical. What we have turned in, we know to be a particular mode of motion. We have not changed the amount of matter involved; indeed, we assume, without specifying and without controversy, that matter is itself indestructible, and the product, whether it be of one kind or another, can only be some form of motion. Whether we can describe it or not is immaterial; but if we agree that heat is vibratory molecular motion, and there be any other kind of a product than heat, it, too, must also be some other form of motion. So, if one is to form a conception of the mechanical origin of electricity, this is the only one he can have—transformed motion.

(2) When heat is the antecedent of electricity, as in the thermo-pile, that which is turned into the pile we know to be molecular motion of a definite kind. That which comes out of it must be some equivalent motion, and if all that went into it were transformed, then all that came out would be transformed, call it by what name we will and let its amount be what it may.

(3) When a conductor is moved in a magnetic field, the energy spent is measurable in foot-pounds, as before, a pressure into a distance. The energy appears in a new form, but the quantity of matter being unchanged, the only changeable factor is the kind of motion, and that the motion is molecular is evident, for the molecules are heated. Mechanical or mass motion is the antecedent, molecular heat motion is the consequent, and the way we know there has been some

intermediate form is that heat is not conducted at the rate which is observed in such a case. Call it by what name one will, some form of motion has been intermediate between the antecedent and the consequent, else we have some other factor of energy to reckon with than ether, matter and motion.

(4) In a galvanic battery, the source of electricity is chemical action; but what is chemical action? Simply an exchange of the constituents of molecules, a change which involves exchange of energy. Molecules capable of doing chemical work are loaded with energy. The chemical products of battery action are molecules of different constitution, with smaller amounts of energy as measured in calories or heat units. If the results of the chemical reaction be prevented from escaping by confining them to the cell itself, the whole energy appears as heat and raises the temperature of the cell. If a so-called circuit be provided, the energy is distributed through it and less heat is spent in the cell; but whether it be in one place or another, the mass of matter involved is not changed, and the variable factor is the motion, the same as in the other cases. The mechanical conceptions appropriate are the transformation of one kind of motion into another kind by the mechanical conditions provided.

(5) Physiological antecedents of electricity are exemplified by the structure and mode of operation of certain muscles in the gymnotus and other electrical animals. The mechanical contraction of them results in an electrical excitation, and, if a proper circuit be provided, in an electric current. The energy of a muscle is derived from food, which is itself but a molecular compound loaded with energy of a kind available for muscular transformation. Bread and butter has more available energy, pound for pound, than has coal, and can be substituted for coal for running an engine. It is not used, because it costs so much more. There is nothing different, so far as the factors of energy go, between the food of an animal and the food of an engine. What becomes of the energy depends upon the kind of structure it acts on. It may be changed into translatory, and the whole

body moves in one direction; or into molecular, and then appears as heat or electrical energy.

If one confines his attention to the only variable factor in the energy in all these cases, and traces out in each just what happens, he will have only motions of one sort or another, at one rate or another, and there is nothing mysterious which enters into the processes.

We will turn now to how electricity manifests itself, and what it can do. It may be well to point out at the outset what has occasionally been stated, but which, in my judgment, has not received the philosophical attention it deserves, namely, that electrical phenomena are reversible, that is, any kind of a physical process which is capable of producing electricity, electricity is itself able to produce. Thus, to name a few: If mechanical motion develops electricity, electricity will produce mechanical motion; the movement of a pith ball is a simple case. If chemical action can produce it, it will produce chemical action, as in the decomposition of water and electroplating. As heat may be its antecedent, so will it produce heat. If magnetism be an antecedent factor, magnetism may be its product. What is called induction may give rise to it in an adjacent conductor, and, likewise, induction may be its effect.

Let us suppose ourselves to be in a building in which a steam engine is at work. There is fuel, the furnace, the boiler, the pipes, the engine with its fly-wheel turning. The fuel burns in the furnace, the water is superheated in the boiler, the steam is directed by the pipes, the piston is moved by the steam pressure, and the fly-wheel rotates because of proper mechanism between it and the piston. No one who has given attention to the successive steps in the process is so puzzled as to feel the need of inventing a particular force, or a new kind of matter, or any agency, at any stage of the process, different from the simple mechanical ones represented by a push or a pull. Even if he cannot see clearly how heat can produce a push, he does not venture to assume a genii to do the work, but for the time is content with saying that if he starts with motion in the

furnace and stops with the motion of the fly-wheel, any assumption of any other factor than some form of motion between the two would be gratuitous. He can truthfully say that he understands the *nature* of that which goes between the furnace and the wheel; that it is some sort of motion, the particular kinds of which he might make out at his leisure.

Suppose once more that, across the highway from this engine house, there is another building, where all sorts of machines—lathes, planers, drills, etc.—are running, but that the source of the power for all this is out of sight, and that one can see no connection between this and the engine on the other side of the street. Would one need to suppose there was anything mysterious between the two—a force, a fluid, an immaterial something? I am asking the question on the supposition that one was not aware of the shaft that might be between the two buildings, and that it was not obvious on simple inspection how the machines got their motions from the engine. I think no one would be puzzled because he did not know just what the intervening mechanism might be. If the boiler were in the one building, and the engine in the other with the machines, he could see nothing moving between them, even if the steam pipes were of glass. If matter of any kind were moving, he could not see it there. He would say there *must* be something moving, or pressure could not be transferred from the one place to the other.

Substitute for the furnace and boiler a galvanic battery or a dynamo; for the machines of the shop, one or more motors with suitable wire connections. When the dynamo goes the motors go; when the dynamo stops the motors stop; nothing can be seen to be turning or moving in any way between them. Is there any necessity for assuming a mysterious agency, or a force of a *nature* different from the visible ones at the two ends of the line? Is it not certain that the question is, how does the motion get from the one to the other, whether there be a wire or not? If there be a wire, it is plain that there is motion in it, for it is heated its whole length, and heat is known to be a mode of motion,

and every molecule which is thus heated must have had some antecedent motions. Whether it be defined or not, and whether it be called by one name or another, are quite immaterial if one is concerned only with the *nature* of the action, whether it be matter or ether, or motion or abracadabra.

Once more: suppose we have a series of active machines. An arc lamp, radiating light waves, gets its energy from the wire which is heated, which in turn gets its energy from the electric current, that from a dynamo, the dynamo from a steam engine, that from a furnace and the chemical actions going on in it. Let us call the chemical actions *A*, the furnace *B*, the engine *C*, the dynamo *D*, the electric lamp *E*, the ether waves *F*. (*Fig. 4.*)

The product of the chemical action is molecular motion, called heat in the furnace. The product of the heat is mechanical motion in the engine. The product of the mechanical motion is electricity in the dynamo. The product of the electrical current in the lamp is light waves in the ether. Nobody hesitates an instant to speak of light waves as forms of motion, for they are described as undulations in the ether at right angles to the direction of the radiation. No one hesitates for an instant to speak of the heat as being molecular motion, nor of the motions of the engine as being mechanical; but when we come to the product of the dynamo, which we call electricity, behold, nearly every one says, not that he does not know what it is, but that no one knows! Does any one venture to say he doesn't know what heat is, because he cannot describe in detail just what goes on in a heated body as it might be described by one who saw with a microscope the movements of the molecules? Let us go back for a moment to the proposition stated early in the address, namely, that if any body of any magnitude moves, it is because some other body in motion and in contact with it

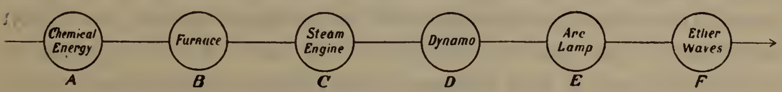

FIG. 4.

has imparted its motion by mechanical pressure. Therefore, the ether waves at F imply continuous motions of some sort from A to F. That they are all motions of ordinary matter from A to E is obvious, because continuous matter is essential for the maintenance of the actions. At E the motions are handed over to the ether, and they are radiated away as light waves.

A puzzling electrical phenomenon has been what has been called its duality—states which are spoken of as positive and negative. Thus, we speak of the positive plate of a battery and the negative pole of a dynamo, and another troublesome condition to idealize has been, how it could be that, in an electric circuit, there could be as much energy at the most remote part as at the source. But, if one will take a limp rope, 8 or 10 feet long, tie its ends together, and then begin to twist it at any point, he will see the twist move in a right-handed spiral on the one hand, and in a left-handed spiral on the other, and each may be traced quite round the circuit; so there will be as much twist, as much motion; and as much energy in one part of the rope as in any other; and if one chooses to call the right-handed twist positive, and the left-handed twist negative, he will have the mechanical phenomenon of energy distribution and the terminology analogous to what they are in an electric circuit. So far, there is no trouble; but one can see the rope as a whole twisting, and nothing can be seen in an electric conductor. Are not the cases more dissimilar than the mechanical analogy would make them seem to be?

Are there any phenomena which imply that rotation is going on in an electrical conductor? There are. An electric arc, which is a current in the air, and is, therefore, less constrained than it is in a conductor, rotates. Especially marked is this when in front of the pole of a magnet; but the rotation may be noticed in an ordinary arc by looking at it with a stroboscopic disk, rotated so as to make the light to the eye intermittent at the rate of four or five hundred per second. A ray of plane polarized light, parallel with a wire conveying a current, has its plane of vibration twisted to the right or left, as the current goes one way or the other

through the wire, and to a degree that depends upon the distance it travels; not only that, but if the ray be sent, by reflection, back through the same field, it is twisted as much more—a phenomenon which convinces one that rotation is going on in the space through which the ray travels. If the ether through which the ray be sent were simply warped or in some static stress, the ray, after reflection, would be brought back to its original plane, which is not the case. This rotation in the ether is produced by what is going on in the wire. The ether waves called light are interpreted to imply that molecules originate them by their vibrations, and that there are as many ether waves per second as of molecular vibrations per second. In like manner, the implication is the same, that if there be rotations in the ether they must be produced by molecular rotation, and there must be as many rotations per second in the ether as there are molecular rotations that produce them. The space about a wire carrying a current is often pictured as filled with whorls indicating this motion, and one must picture to himself, not the wire as a whole rotating, but each individual molecule independently. But one is aware that the molecules of a conductor are practically in contact with each other, and that if one for any reason rotates, the next one to it would, from frictional action, cause the one it touched to rotate in the opposite direction, whereas, the evidence goes to show that all rotation is in the same direction.

How can this be explained mechanically? Recall the kind of action that constitutes heat, that it is not translatory action in any degree, but vibratory, in the sense of a change of form of an elastic body, and this, too, of the atoms that make up the molecules of whatever sort. Each atom is so far independent of every other atom in the molecule that it can vibrate in this way, else it could not be heated. The greater the amplitude of vibration, the more free space to move in, and continuous contact of atoms is incompatible with the mechanics of heat. There must, therefore, be impact and freedom alternating with each other in all degrees in a heated body. If, in any way, the atoms themselves *were* made to rotate, their heat impacts not only would restrain

the rotations, but the energy also of the rotation mōtion would increase the vibrations; that is, the heat would be correspondingly increased, which is what happens always when an electric current is in a conductor. It appears that the colder a body is the less electric resistance it has, and the indications are that at absolute zero there is no resistance; that is, impacts do not retard rotation, but it is also apparent that any current sent through a conductor at that temperature would at once heat it. This is the same as saying that an electric current could not be sent through a conductor at absolute zero.

So far, mechanical conceptions are in accordance with electrical phenomena, but there are several others yet to be noted. I have spoken of electrical phenomena as molecular or atomic phenomena, and there is one more in that category which is well enough known, and which is so important and suggestive, that I wonder its significance has not been seen by those who have sought to interpret electrical phenomena. I refer to the fact that electricity cannot be transmitted through a vacuum. An electric arc begins to spread out as the density of the air decreases, and presently it is extinguished. An induction spark that will jump 2 or 3 feet in air cannot be made to bridge the tenth of an inch in an ordinary vacuum. A vacuum is a perfect non-conductor of electricity. Is there more than one possible interpretation to this, namely, that electricity is fundamentally a molecular and atomic phenomenon, and in the absence of molecules cannot exist? One may say: "Electrical *action* is not hindered by a vacuum," which is true, but has quite another interpretation than the implication that electricity is an ether phenomenon. The heat of the sun in some way gets to the earth, but what takes place in the ether is not heat conduction. There is no heat in space, and no one is at liberty to say, or to think, that there can be heat in the absence of matter.

When heat has been transformed into ether waves it is no longer heat, call it by what name one will. Formerly such waves were called heat waves; no one, properly informed, does that now. In like manner, if electrical motions

or conditions in matter be transformed, no matter how, it is no longer proper to speak of such transformed motions or conditions as electricity. Thus, if electrical energy be transformed into heat, no one thinks of speaking of the latter as electrical. If the electrical energy be transformed into mechanical of any sort, no one thinks of calling the latter electrical because of its antecedent. If electrical motions be transformed into ether actions of any kind, why should we continue to speak of the transformed motions or energy as being electrical? Electricity may be the antecedent, in the same sense as mechanical motion of a bullet may be the antecedent of the heat developed when the latter strikes the target; and if it be granted that a vacuum is a perfect non-conductor of electricity, then it is manifestly improper to speak of any phenomenon in the ether as an electrical phenomenon. It is from the failure to make this distinction that most of the trouble has come in thinking on this subject. Some have given all their attention to what goes on in matter, and have called that electricity; others have given their attention to what goes on in the ether, and have called that electricity, and some have considered both as being the same thing, and have been confounded.

Let us consider what is the relation between an electrified body and the ether about it.

When a body is electrified, the latter at the same time creates an ether stress about it, which is called an electric field. The ether stress may be considered as a warp in the distribution of the energy about the body, by the new positions given to the molecules by the process of electrification. I have already said that the evidence from other sources is that atoms, rather than molecules, in larger masses, are what affect the ether. One needs to inquire for what knowledge we have as to the constitution of matter or of atoms. There is only one hypothesis to-day that has any degree of probability; that is the vortex-ring theory, which describes an atom as being a vortex ring of ether, in the ether. It possesses a definite amount of energy in vir-

tue of the motion which constitutes it, and this motion differentiates it from the surrounding ether, giving it dimensions, elasticity, momentum, and the possibility of translatory, rotary, vibratory motions and combinations of them. Without going further into this, it is sufficient, for a mechanical conception, that one should have so much in mind, as it will vastly help in forming a mechanical conception of reactions between atoms and the ether. An exchange of energy between such an atom and the ether is not an exchange between different kinds of things, but between different conditions of the same thing. Next, it should be remembered that all the elements are magnetic in some degree. This means that they are themselves magnets, and every magnet has a magnetic field unlimited in extent, which can almost be regarded as a part of itself. If a magnet of any size be moved, its field is moved with it, and if in any way the magnetism be increased or diminished, the field changes correspondingly.

Assume a straight bar electro-magnet in circuit, so that a current can be made intermittent, say, once a second. When the circuit is closed and the magnet is made, the field at once is formed and travels outwards at the rate of 186,000 miles per second. When the current stops, the field adjacent is destroyed. Another closure develops the field again, which, like the other, travels outwards; and so there may be formed a series of waves in the ether, each 186,000 miles long, with an electro-magnetic antecedent. If the circuit were closed ten times a second, the waves would be 18,600 miles long; if 186,000 times a second, they would be but 1 mile long. If 400 million of millions times a second, they would be but the forty-thousandth of an inch long, and would then affect the eye, and we should call them light waves, but the latter would not differ from the first wave in any particular except in length. As it is proved that such electro-magnetic waves have all the characteristics of light, it follows that they must originate with electro-magnetic action, that is, in the changing magnetism of a magnetic body. This makes it needful to assume that the atoms which originate waves are magnets, as they are

experimentally found to be. But how can a magnet, not subject to a varying current, change its magnetic field? The strength or density of a magnetic field depends upon the form of the magnet. When the poles are near together, the field is densest; when the magnet is bent back to a straight bar, the field is rarest or weakest, and a change in the form of the magnet from a U-form to a straight bar would result in a change of the magnetic field within its greatest limits. A few turns of wire wound about the poles of an ordinary U-magnet, and connected to an ordinary magnetic telephone, will enable one, listening to the latter, to hear the pitch of the former loudly reproduced when the magnet is struck like a tuning-fork so as to vibrate. This shows that the field of the magnet changes at the same rate as the vibrations.

Assume that the magnet becomes smaller and smaller until it is of the dimensions of an atom, say, for an approximation, the fifty-millionth of an inch. It would still have its field; it would still be elastic and capable of vibration, but at an enormously rapid rate; but its vibration would change its field in the same way, and so there would be formed those waves in the ether, which, because they are so short that they can affect the eye, we call light. The mechanical conceptions are legitimate, because based upon experiments having ranges through nearly the whole gamut as waves in ether.

The idea implies that every atom has what may be loosely called an electro-magnetic grip upon the whole of the ether, and any change in the former brings some change in the latter.

Lastly, the phenomenon called induction may be mechanically conceived.

It is well known that a current in a conductor makes a magnet of the wire, and gives it an electro-magnetic field, so that other magnets in its neighborhood are twisted in a way tending to set them at right angles to the wire. Also, if another wire be adjacent to the first, an electric current having an opposite direction is induced in it. Thus:

Consider a permanent magnet *A* (*Fig. 5*), free to turn on

an axis in the direction of the arrow. If there be other free magnets, *B* and *C*, in line, they will assume such positions that their similar poles all point one way. Let *A* be twisted to a position at right angles, then *B* will turn, but in the opposite direction, and *C* likewise. That is, if *A* turn in the direction of the hands of a clock, *B* and *C* will turn in the opposite direction. These are simply the observed movements of large magnets. Imagine that these magnets be reduced to atomic dimensions, yet retaining their magnetic qualities, poles and fields. Would they not evidently move in the same way and for the same reasons? If it be true that a magnet field always so acts upon another as to tend by rotation to set the latter into a certain position with reference to the stress in that field, then, *wherever there is a changing magnetic field, there the atoms are being adjusted by it.*

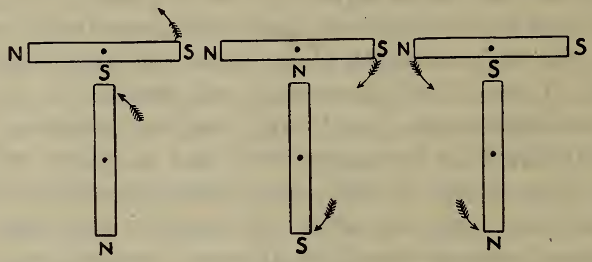

FIG. 5.

Suppose we have a line of magnetic needles free to turn, hundreds or thousands of them, but disarranged. Let a strong magnetic field be produced at one end of the line. The field would be strongest and best conducted along the magnet line, but every magnet in the line would be compelled to rotate, and if the first were kept rotating the rotation would be kept up along the whole line. This would be a mechanical illustration of how an electric current travels in a conductor. The rotations are of the atomic sort, and are at right angles to the direction of the conductor.

That which makes the magnets move is inductive magnetic ether stress, but the advancing motion represents mechanical energy of rotation, and it is this motion with the resulting friction which causes the heat in a conductor.

What I would like to emphasize is, that the action in the ether is not electric action, but more properly the result of electro-magnetic action. Whatever name be given to it, and however it comes about, there is no good reason for calling any kind of an ether action electrical.

Electric action, like magnetic action, begins and ends in matter. It is subject to transformations into thermal and mechanical actions, also into ether stress—right-handed or left-handed—which, in turn, can similarly affect other matter, but with opposite polarities.

In his "Modern Views of Electricity," Prof. O. J. Lodge warns us, in a way I quite approve, that perhaps, after all, there is no such *thing* as electricity—that electrification and electric energy may be terms to be kept; but if electricity as a term be held to imply a force, a fluid, an imponderable, or a thing which could be described by some one who knew enough, then it has no degree of probability, for spinning atomic magnets seem capable of developing all the electrical phenomena we meet.

NOTES AND COMMENTS.*

DUCTILE CAST IRON.

We learn from the *Iron Age* that the East Chicago Foundry Company, whose works are at East Chicago, Ind., are placing a new product on the market, which they term "ductile cast iron." Their experiments, which have extended over the past year and a half, have been so satisfactory that they have decided to abandon their former business of making general iron castings, and have fitted up their foundry to make ductile iron castings exclusively. They are prepared to make castings of this character ranging from 10 pounds to 10,000 pounds in weight, which are not only solid, homogeneous and free from blow-holes, but which also may be drawn under the hammer or perfectly welded, and will work well under the planer or other tools.

The samples shown by the company are of an extraordinary character, suggesting many of the qualities of steel, but at the same time presenting features peculiar to iron. The metal is remarkable for its strength coupled with its ductility. A test bar, cast with the breaking section curved in on both sides, instead of being cut out afterwards as usual, was tested by Fraser &

* From the Secretary's monthly reports.

Chalmers, and showed a tensile strength of 63,000 pounds to the square inch. Other tests have shown over 80,000 pounds. After being heated to a dull red and plunged into cold water, it can be cut easily with a file, showing that it takes no temper. Specimens of castings are shown which have had portions heated and drawn out flat under the hammer, afterward being twisted cold and pounded flat, without a sign of fracture. Gates from castings are shown which have stood remarkable torture of this character. A notable piece of work is a heavy chain, of which the links were cast open, then joined and the open spaces welded without the use of flux. Valve stems, crank shafts and other similar pieces are shown which have been finished to pattern in a lathe, exhibiting a smooth surface without a suspicion of a blow-hole. Intricate castings are exhibited which have been reproduced regularly without a failure, while a very high percentage of losses has been reported when made by other methods of producing very strong castings.

It is the intention of the company to meet the demand for castings of the highest grade, competing with drop forgings and aiming to produce shapes which are difficult to work under a hammer, but for which castings have heretofore not been found sufficiently strong and trustworthy. It has been shown by extensive experiments that the castings made by this company are well adapted for electrical apparatus, owing to their high conductivity. Another important field has thus been opened which is full of possibilities.

THE PASSING OF WELSH SUPREMACY.

We quote the following from the editorial comments of the *Iron Age* on the apparent collapse of the tin-plate industry of Wales:

* * * In the collapse of the Welsh tin-plate trade we have an illustration of a business calamity on a tremendous scale. Possibly in the history of the world a parallel case cannot be found, in which, without the intervention of war or religious or political persecution, a flourishing industry of such vast dimensions has been sapped and almost destroyed in less than a decade The accounts which are now being published about the hard times in Wales, the stoppage of works, the ruin of once opulent manufacturers, the savage reductions in wages, and the despair of those who can see no market for their products, are distressing in the extreme.

The assumption appears safe that even the most enthusiastic advocate of an American tin-plate industry did not dream that within the short space of six years from the establishment of tin-plate factories on this side of the Atlantic the Welsh tin plate trade would be in a state of decay. The Welsh manufacturers were known to be sturdy fighters; their business had been established for 150 years, during which time they had monopolized the tin-plate business of the world; they were believed to be in possession of resources in cheap material and an abundance of cheap labor, whose real power had never been seriously tested, and they had surrounded their business with a veil of mystery and fortified it by such a formidable barrier of awe-inspiring trade terms that little wonder exists that many Americans

doubted the wisdom of the attempt to set up an opposition industry here. In fact, the greatest doubters were among those who were most intimately acquainted with Welsh tin-plate manufacturers and their methods. So short a time has elapsed since American tin-plates began to be an article of commerce, that it is easy to remember how confident were the Welsh makers that the business would never be established here, and how valiantly they talked of the day when American tin-plate factories would be roofless and their amateur workmen scattered to pursue other occupations. They would not believe some of their most wide-awake colleagues who visited this country in 1891 and 1892 and carried back "scare" reports of what they had seen. Even so late as last summer, when the price of steel rose here, they dreamed dreams and saw visions in which they were again reveling in the undisputed occupancy of American markets. But with the fall in steel their visions faded and, perhaps, they then for the last time permitted themselves to hope of regaining their standing in this country. That hope has been succeeded by blank despair, as purchasers of Welsh tin-plates on American account are now seen to fall off rapidly from month to month, while American tin-plate works are being enlarged and their number increased. * * *

THE COMMERCIAL VALUE OF APPLIED CHEMISTRY.

Professor Dewar's recent lecture at the Royal Institution was a rapid survey of the galloping pace at which chemical discovery of value in the arts has lately proceeded, says the London *Chronicle*. It was a complete justification of Mr. Ludwig Mond's dictum that chemical research spells commercial success.

Take, for instance, what Mr. Mond himself has brought to light and utilized, all through his attempts to improve the gas battery first invented by Lord Justice Grove. Why cannot we turn coal directly into electricity without the cumbrous boiler, steam engine and dynamo process intervening—burn it up as you burn up zinc in a galvanic battery? Well, the idea is very magnificent, but not yet within the range of practical science.

But the suggestion that carbonic oxide might be used in some way led Mr. Mond to discover a strange and totally unexpected property of this gas, namely, that it will directly unite with metallic iron and nickel to form gases which are called carbonyls of these metals. Could anything be more strange than the idea of iron as gas at an ordinary temperature? And could anything be more valuable? For as soon as you heat these carbonyls they give out the metal again with the greatest facility. The result is, that Mr. Mond is now using carbonic oxide to extract nickel from its ores. He gets nickel carbonyl as a gas, subsequently heats it to make it part with its nickel, and sends back the carbonic oxide to extract some more. In this way pure nickel can be obtained, for the gas will only pick up the nickel.

Professor Dewar also described the famous Castner process for getting pure soda from common salt. Here we have electrolysis at work once more, but with a movable electrode in the shape of a flowing stream of mercury,

which bears away the metallic sodium in amalgamic solution as fast as it is separated from the salt. The amalgam then passes into water, where the sodium dissolves as hydrate, leaving the mercury free to go round again.

But there is something more than this. As the sodium dissolves it generates electricity. Formerly this electricity was generated in the electrolytic bath itself, and obstructed the operating current by setting up a "back current" on its own account. Now, the "back current" being separately generated, is made to travel the right way, and supplement instead of obstructing the working current.

Finally, Professor Dewar illustrated the discovery of the effect of the oxides of the rare earths, such as those of zirconium, thorium and lanthanum, in transforming heat into light. This is the principle of the incandescent gas burners. The now familiar mantle, which is suspended in an atmospheric or Bunsen burner, and glows so brilliantly, is made (as Professor Dewar showed) by saturating a cotton mantle with salts of these metals and then incinerating it. The organic cotton is all burned away, leaving nothing but a skeleton mantle of oxides and silica. When these are suspended in the colorless gas flame they glow in the brilliant fashion now so familiar, far surpassing the incandescence which can be obtained from platinum, magnesium, lime and other substances heated to the same point.

FORMATION OF CYANOGEN FROM AMMONIA.

The occurrence of cyanide of potassium in blast-furnaces was first, in 1837, observed by Thomas Clark, on the Clyde. The crusts and efflorescences forming about the tuyeres, especially after scouring, consisted of nearly equal parts of cyanide and of potash. The observation was soon confirmed from other parts, but no adequate explanation of the occurrence has been given. The investigation which Dr. E. Bergmann has started, in conjunction with Dr. Bueb, on the instigation of Professor Bunte, does not settle the question whether or not the cyanogen in such cases is really derived from the free nitrogen of the atmosphere; but the experiments have a high practical interest. Dr. Bueb has not yet published his researches; Dr. Bergmann gives a detailed account of his share of the work in *Schilling's Journal für Gasbeleuchtung*. The study concerns the action of ammonia, diluted or not with illuminating gas or Dowson gas, on glowing charcoal. From a reservoir, provided with a gas meter, the gas passed through the bottle in which the ammonia was generated. The dried gases then entered a porcelain tube, filled with charcoal, which was heated up to 1,180° C. in a Fletcher gas stove; an aspirator was joined to the other end. The temperature was ascertained by means of Princeps' alloys. At 800° only 4 per cent. of the nitrogen supplied as ammonia was converted into cyanogen; at 1,000° 24 per cent. When illuminating gas was admixed, 60 per cent. could be gained at the highest temperature applied, 1,180°. Of the remaining 40 per cent. of the ammonia, 20 per cent. was recovered as ammonia, and 20 per cent. decomposed into nitrogen and hydrogen. The coal gas acts either simply as a diluent—and

the experiments prove that a concentrated current of ammonia is not profitable—or it may be decomposed according to the formula $C_2 + 2NH_3 = 2CNH + 2H_2$. If the latter be the case, gas containing higher hydrocarbons should prove more effective; the addition of penthane was found useless, however, if not deleterious. There is a third possibility, $CO + NH_3 = CNH + H_2O$. This reaction would be important for Dowson gas. When working simply according to this formula, that is, without using charcoal, a little cyanogen was, indeed, formed, but the quantity was very slight. The experiments were made with about 6 grams of ammonia, 40 or 50 liters of the other gases, and lasted from one to three hours. The following is a summary of the results: Hydrocyanic acid, and not cyanide of ammonia, is formed when ammonia is passed over glowing charcoal; by-products are nitrogen and hydrogen, never methane. The addition of coal gas increases the yield of cyanogen, and keeps down the splitting up of ammonia into its constituents. Hydrocarbons of higher molecular weight seem to prevent the decomposition of the ammonia, becoming themselves decomposed, and their admixture is hence not advisable. Carbonic oxide behaves like coal gas, but it favors the splitting up of ammonia; the same applies to Dowson gas. These gases act as diluents; the diluted ammonia is not so easily split up as the concentrated ammonia. The current should not be too rapid. The temperature depends upon the nature of the gases added; on the whole, a temperature of 1,100° gives the best results. A certain percentage of ammonia always escapes unattacked. This percentage increases in the presence of hydrocarbons of higher molecular weight. Dr. Bergmann does not discuss the practical bearing of these researches.—*Engineering.*

THE MANUFACTURE OF ARTIFICIAL SILK.

London *Nature* has the following interesting item apropos to the impending introduction into England of the manufacture of artificial silk from cellulose by the process devised by M. de Chardonnet, which was described in the *Journal* several years ago, viz:

"Lancashire is on the eve of some important expansions of the textile trades, for, from an interesting article in the *Times*, it appears that the manufacture of artificial silk from wood pulp will shortly be added to her industries.

"At present the wood-silk comes from France, large works having been established at Besançon under patents granted to Count Hilaire de Chardonnet, who discovered the process, and first established in 1893 the fact that it might be made commercially successful. The demand for the new commodity increased so considerably that the idea of introducing its manufacture into England was mooted, with the result that a number of silk and cotton manufacturers met to discuss the question, and finally sent out to Besançon a deputation, consisting of some of their own number, an engineer, a chemist, and a lawyer, to investigate the subject thoroughly. This was done, and the outlook was found to be so promising that certain concessions have been

secured and a company is now in process of formation, and, to begin with, a factory, which will cost £30,000, is to be built near to Manchester for the manufacture of artificial silk yarn from wood pulp, for sale to weavers, who will work it up by means of their existing machinery.

"The way in which wood pulp can be converted into silk yarn is explained in the *Times*. The pulp, thoroughly cleansed, and looking very much like thick gum, is put in cylinders, from which it is forced by pneumatic pressure into pipes passing into the spinning department. Here the machinery looks like that employed in Lancashire spinning sheds, except that one of the pipes referred to runs along each set of machines. These pipes are supplied with small taps, fixed close together, and each tap has a glass tube, about the size of a gas burner, at the extreme point of which is a minute aperture through which the filaments pass. These glass tubes are known as 'glass silkworms,' and some 12,000 of them are in use in the factory at Besançon. The effect of the pneumatic pressure in the cylinders referred to above is to force the liquid matter not only along the iron tubes, but also, when the small taps are turned on, through each of the glass silkworms. It appears there is a scarcely perceptible globule. This a girl touches with her thumb, to which it adheres, and she draws out an almost invisible filament, which she passes through the guides and on to the bobbin. Then, one by one, she takes eight, ten or twelve other such filaments, according to the thickness of the thread to be made, and passes them through the same guides and on to the same bobbin. This done, she presses them together with her thumb and forefinger, at a certain point between the glass silkworms and the guides. Not only do they adhere, but thenceforward the filaments will continue to meet and adhere at that point, however long the machinery may be kept running. In this way the whole frame will soon be set at work, the threads not breaking until the bobbin is full, when they break automatically, while they are all of a uniform thickness. The new product is said to take dye much more readily than the natural silk. The chief difference in appearance between the natural and the artificial silk is in the greater luster of the latter. The success already secured by the new process in France is such that the introduction of the industry into Lancashire is expected to produce something like revolution in the conditions of trade there, not only by bringing into existence a new occupation, but also by finding more work for a good deal of the weaving machinery that is now only partially employed."

THE INVISIBLE SPECTRUM.

The statement is interesting as coming from Prof. William Huggins, foremost in such researches, that beyond the violet end of the spectrum there is a whole gamut of invisible rays which only reveal themselves by their effect in promoting chemical action, and similarly, beyond the other end of the visible scale, the deep red, there is a gamut of invisible or dark rays which are only perceived by their heating effects. Some idea, he says, of the importance of the "ultra red" may be gathered from the fact that it has been traced to a dis-

tance nearly ten times as long as the whole range of the visible or light-giving region of the spectrum; to learn, then, the character of these mysterious dark rays, it has been clearly necessary for science to fit itself with some new sort of eyes for seeing what ordinary eyes cannot, namely, heat rays and chemical rays, and, in respect of the latter, the photographic plate has brought out some wonderful facts, while the bolometer has been used in feeling for absorption lines in the great invisible spectrum which lies beyond the red.

TECHNICAL NOTES.

For Plating Aluminum with Copper, Margot prepares the aluminum surface by immersion in a bath of an alkaline carbonate (caustic alkali should answer better.—Ed.), then a thorough rinsing in clear water, followed by a dip in a 5 per cent. solution of hydrochloric acid and subsequent rinsing. The article is now immersed in a weak and slightly acid solution of copper sulphate, which causes a thin but adherent coating of copper. The article is then removed to the electrolytic bath, in which the coating may be made as heavy as desired.

For Etching Letters, Names or Designs on metallic goods, such as knives, for instance, the *Zeit. f. Electrochem.* gives the following directions: The objects are covered with the following mixture: 1 liter of naphtha, ⅛ kilogram of carbon bisulphide, 2 kilograms of pulverized resin, and 1·5 kilograms of chloride of copper. After covering with a thin layer of this, the stencil or type is washed with a weak solution of potash and pressed on the surface, which is then washed, after which it is wet with a weak solution of sal-ammoniac, through which a current is passed, which then etches the metal where the insulating coat has been removed.

A Pavement used in Vienna consists of granulated cork mixed with mineral asphalt and other cohesive substances, compressed into blocks of suitable size and form. Among the numerous advantages set forth in its behalf are cleanliness, noiselessness, durability, elasticity, freedom from slipperiness, whether wet or dry, and moderate cost. Unlike wood, it is non-absorbent, and, consequently, inodorous. It presents the minimum resistance to traction, and, being elastic under passing loads, does away with the vibration caused by heavy teaming. The blocks are embedded in tar, and rest upon a concrete base 6 inches thick. When taken up for examination they have exhibited, when compared with new ones, a reduced thickness by wear of less than ⅛ inch—this in the case of a section of a London street leading to the Great Eastern Railway station, subjected to continuous heavy traffic, the blocks having been in use nearly two years.

Electricity Direct from Coal.—Two processes have recently been described by which electricity can be produced direct from combustion of coal. One is that of Dr. W. W. Jacques, and consists in blowing air through a bath

of fused caustic soda, with a carbon anode and iron cathode, whereby he obtains a very large current, but the voltage is low.

Dr. Alfred Coehn, of Germany, takes as a basis for his work the principle that a method for obtaining electrical energy direct from the oxidation of carbon may reasonably be sought, first, by determining the conditions under which carbon can be attacked in an electrolyte by the aid of an external circuit, and thereby adapting these conditions for the production of a current.

By experiment, Dr. Coehn has reached the following conclusions:

(1) It is possible to prepare a solution of carbon by electrolytic means.

(2) Carbon can be separated from such a solution at the cathode.

(3) A cell may be made having carbon for its soluble electrode.

Neither of these authors has made the details of his method sufficiently clear to permit of an intelligent criticism.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, June 17, 1896.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 17, 1896.

JOS. M. WILSON, President, in the chair.

Present, 225 members and visitors.

Additions to membership since last report, 8.

The Secretary reported two vacancies in the Committee on Science and the Arts, caused by the resignations, respectively, of Mr. D. E. Crosby and Mr. Henry Brinton. An election to fill the vacancies resulted in the choice of Mr. Clayton W. Pike for the unexpired term of Mr. Crosby, and Mr. Louis E. Levy for the unexpired term of Mr. Brinton.

Mr. Chas. A. Hexamer, Secretary of the Philadelphia Board of Fire Underwriters, read a paper descriptive of a series of tests of the "Fire-retarding Qualities of Wire Glass," recently made under his directions. (The paper will appear in the *Journal.*)

Mr. W. N. Jennings exhibited and commented upon a series of lantern views from his own photographs, showing the destructive effects of the tornado which lately devastated the city of St. Louis, Mo., and its vicinity.

Prof. F. L. Garrison supplemented the previous speaker's comments with some additional views and remarks on the general subject. The subject was further discussed by Messrs. Chas. James and Jacob Reese.

Prof. Angelo Heilprin exhibited and described an improved window of his invention, designed especially for service as a railway-car window.

The Secretary's report followed, of which an abstract appears in this impression of the *Journal.*

Adjourned.

WM. H. WAHL, *Secretary.*

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THE FRANKLIN INSTITUTE.

Stated Meeting, June 17, 1896.

MR. JOS. M. WILSON, President, in the chair.

THE FIRE-RETARDING QUALITIES OF WIRED-GLASS.

BY CHAS. A. HEXAMER, C. E.,
Member of the Institute, Secretary of the Philadelphia Fire-Underwriters' Association.

On November 1, 1893, the Committee of Science and the Arts of the Franklin Institute adopted a report recommending the award, to Frank Shuman, of the John Scott Legacy Premium and Medal, for his machine and process for producing wired-glass. This report, at some length, discusses the varied uses to which wired-glass can be put, and its superiority in numerous applications over the ordinary glass. The question of the fire-retarding qualities of the

wired-glass, however, was passed over without special comment.

In the autumn of 1893, my attention was called to some fire-doors in the large establishment of the J. B. Stetson Company, of this city. These doors, which were provided for the purpose of protecting the opening in each story to a brick elevator-shaft, had a large sheet of wired-glass inserted as a transparent panel. The manager of the factory, Mr. Theo. C. Search, had made a number of fire tests of wired-glass, and, as a result, had come to the conclusion that the material would answer as a fire-retardent. The writer is of the opinion that the case cited is the first instance of using wired-glass for this purpose, although, as stated in the report of the Committee of Science and the Arts, the first patent for wired-glass was granted in 1855, to an Englishman named Newton, for "a fire-proof and burglar-proof glass."

In December of the year 1893, Mr. W. S. Lemmon, Inspector of the Newark (N. J.) Committee of the Underwriters' Association of the Middle Department, requested an owner in that city to place wired-glass in two windows of his warehouse, to protect it from external exposure. This resulted in a test of the fire-retarding quality of wired-glass in Newark, which is described by Mr. Lemmon, in a letter, as follows:

"A small brick building, about 6 x 10 feet, was built, in which were placed the following windows, all glazed with wired-glass, $\frac{1}{2}$ inch in thickness: one 20 x 80 inches, one 28 x 80 inches and one 30 x 80 inches. In the building, a fire was made for half an hour, a high degree of heat being developed. When the glass became red hot, cold water was turned on by the city Fire Department, under 60 pounds pressure, through the regular fire hose. In addition to the throwing of water on the glass, the chief of the Fire Department tried, without success, to throw a half brick through the glass while it was red hot; this was to show the result of falling walls against the glass when in actual use for exposure purposes."

In this test, the frames holding the wired-glass in place

were constructed of angle iron and of galvanized sheet-iron. The intense heat warped and bent the metal work, but the glass did not fall out on account of the warping. Mr. Lemmon further reports that since December, 1893, nearly eighty windows in his city had been constructed of wired-glass, in metal frames, to protect buildings against outside exposure, and in a number of cases actual fire tests proved the value of the wired-glass for the purpose designated.

FIG. 1.

In our own city, besides being used in a number of fire-doors in stairway- and elevator-shafts, wired-glass partitions have been erected in a number of buildings.

At the request of the Mississippi Glass Company, which controls the manufacture of wired-glass, the writer, in conjunction with Inspector Wm. McDevitt, made a series of tests of the fire resisting qualities of wired-glass, the main test being described in the following report made to the Committee of the Philadelphia Fire Underwriters' Association :

REPORT ON TEST OF THE FIRE-RESISTING QUALITY OF WIRED-GLASS.

A brick test-house, about 3 x 4 feet, inside measurement, and 9 feet high, was constructed in the yard of the Pennsylvania Iron Works, near Fiftieth Street and Merion Avenue. In one side of this structure a wired-glass window was fastened in a wooden frame, covered with lock-jointed tin. In another side, a Philadelphia standard fire-door was hung. The upper part of this door had a pane of wired-glass, 18 x 24 inches, set into a wooden metal-covered frame. The entire roof of the test-house was replaced by a skylight, the sash being constructed of wood, metal-covered; one side of this skylight being provided with three lights of ¼-inch ordinary rough glass, the

FIG. 2.

other side with three lights of wired-glass. The entire structure was constructed by John J. Husband, in accordance with specifications furnished by the Secretary. The wired-glass used was ¼ inch thick, and was manufactured by the Mississippi Glass Company, of St. Louis.

In order to make the fire test as severe as possible, iron grate-bars were placed in the bottom of the test-house, and openings were left in the wall near the ground for free draught. The test house was filled for two-thirds of its height with wood, approximately one-half cord being used. After treating the wood with a liberal allowance of coal oil and resin, the fire was started. In a few minutes the ordinary rough glass in the skylight cracked and pieces began to fall into the fire. The wired-glass in the fire-door soon became red

hot, so that a piece of paper held against it on the outside was easily ignited. The three plates of wired-glass in skylight, subjected to the entire heat of the fire, also became red hot, but retained their positions throughout the test. At the end of thirty minutes, water was thrown on the fire and also on the hot glass. After the fire was extinguished, the three plates of glass in the skylight were found to be cracked into countless pieces, but still adhering together, forming one sheet. The window light, which, as the result showed, was not properly secured to the frame, was found to be of same condition as skylight glass, excepting that a large crack had developed. The plate of glass in the standard fire-door was cracked, the same as the skylight; but having been

FIG. 3.

well secured into the door frame, it did not give way. The action of the fire on the wooden metal-covered skylight and window frame showed conclusively that this class of construction is far superior to iron framing, no warping or giving way of any portion of the frames being noticed. The fire-door in direct contact with the fire showed but little buckling on the inner side, and no signs of giving way. On removing the tin covering, it was found, however, that the inner layer of 1-inch boards was completely charred through, but that the second layer was only slightly damaged.

The conclusions to be drawn from the test appear to be as follows:

(1) Wired-glass can safely be used in skylights, and in such situations will withstand a severe fire and will not give way when water is thrown on it. A

wooden framing for skylight, covered with tin, all seams lock-jointed and concealed-nailed, is superior in fire-resisting quality to iron framing.

(2) Wired-glass in wooden sash, covered with tin, all seams lock-jointed and concealed-nailed, can safely be used for windows toward an external exposure.

(3) Wired-glass can safely be used in fire-doors to elevator shafts and stairway towers, where it is necessary to light said shafts.

(4) In office buildings, hotels, etc., where it is undesirable to have elevator shafts entirely enclosed and dark, wired-glass permanently built into a brick or terra-cotta shaft, or arranged in a wood metal-covered frame, can safely be used.

(5) Wired-glass plates, securely fastened in standard fire-shutters, can safely be used toward an external exposure. In this case, the fact that a possible fire in a building, all windows of which are protected by fire-shutters, can much more readily be detected from the outside through the wired-glass, is of importance.

Mr. Edward Atkinson, President of the Boston Manufacturers' Mutual Insurance Company, witnessed a test of the fire-retarding quality of wired-glass, in Boston. I quote from Circular No. 69, issued by him in April of this year, as follows:

FIRE-RETARDENT WINDOWS.

There are many places in our risks where it would be very desirable to brick up windows if the light could be spared, but where the requirements for light render it necessary to leave the spaces as they are, often protected with automatic shutters, but sometimes under such conditions that the risk must remain unguarded.

The intervention of wired-glass will, in such cases and in many others, suffice to retard the passage of fire in a fully adequate manner. This glass, originally invented for skylights, is now being applied to fire-retardent purposes. It has been introduced in some of the Western cities, around elevators, in place of the ordinary iron cages. It may be used in our risks for similar purposes.

First, it may be remarked that while, at the beginning, when used for skylights, some defects were disclosed in the differential strain on the glass and the wire under the heat of the sun, that fault is claimed to have been entirely removed. It would not affect the present purpose.

Second, a test of the fire-resisting properties of this wired-glass was witnessed by the undersigned in the vicinity of the Boston Plate Glass Company, on A Street, South Boston. What might be called an iron stove was constructed in the form of a fireplace with a wired-glass blower. It was 3 feet high, 1 foot in depth from face to back, 2 feet wide on front. It was set up on bricks, so as to give a draught all around, and was open at the top. The plate of glass which formed the blower was 18 x 34 inches. This fireplace

was filled to the top with hard wood, and resinous wood upon which kerosene oil had been poured, which was set on fire, resting in front against the glass.

The first effect was to cover the inside of the glass with soot, but after about fifteen minutes the soot was burned off, leaving the glass clear, as at the beginning. The stove was re-charged, and this intense heat affected the glass for nearly half an hour. A stream of cold water was then thrown on the glass from the outside. Presently the fire was put out with another stream and the glass was showered from within. The effect was to crack the glass into millions of pieces; but, being held by the wire, none fell out, neither did the glass spring or bend. It held its place even while the iron of the stove was twisted and bent.

This glass has already been placed at dangerous points in a few of our risks, and may be recommended in all places where the light must be retained, but where it is desirable to put in a fire-retardent material. We have as yet no experience in the test of this kind of window under actual fire.

The glass on which these tests have been made, which is intended for windows or doors, is ¼ inch thick, but it is made up to 1 inch in thickness. The ¼ inch is, of course, too heavy for the ordinary window frame, nor should any wood be used in the setting of the glass unless absolutely protected. Instructions will be given for placing it in metal frames. This glass is made up to 1 inch in thickness, and that thickness, properly supported beneath, might in many places be suitable to put into floors for the purpose of giving light in dark basements or elsewhere; of course, being placed so as not to be subjected to trucks with iron wheels or other danger of chipping.

It is clearly indicated from the above that wired-glass can safely be used as a fire-retardent in numerous ways. From personal experience, I am led to believe that metal-covered wood framing is superior to iron frames for holding the glass in place.

In closing, I would say that the capability of the wired-glass to withstand a temperature beyond the melting point of glass, appears to be attributable to the fact that the network of wire in the glass acts as a good conductor of heat, and thereby prevents the accumulation of sufficient heat to melt the glass; and although it may thereby be softened and rendered pliable, the network of wire prevents the glass from giving way by reason of its own weight when softened by the heat.

The accompanying illustrations will serve to render the preceding descriptions of tests more intelligible.

Fig. 1 shows a window of wired-glass in iron framing, built in a brick wall of a building in Newark, N. J. This window was subjected to a very severe fire, which ultimately destroyed the entire building. The photograph was taken several weeks after the fire.

Fig. 2 shows the brick test-house in the yard of the Pennsylvania Iron Works, Philadelphia, before being subjected to the fire test.

Fig. 3 shows the test-house after having been subjected to the fire test.

PANTASOTE, A NEW FABRIC.

[*Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the products manufactured by the Pantasote Leather Company, of Passaic, N. J.*]

[No. 1772.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 9, 1895.

The Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating pantasote leather, reports as follows:

The products, called by the manufacturers "Pantasote," include fabrics of various kinds intended to serve the same uses as leather in upholstering, carriage-furnishing, book-binding, trunk- and bag-making, mural decoration, etc.

It is made by applying a composition (of which the ingredients and mode of treatment are not disclosed), to the surface of textile fabrics of various kinds, and paper. The successive steps in the process of manufacture are described in sufficient detail to enable it to be clearly understood, in a communication furnished by the manufacturers, and which accompanies this report as an appendix.* These details, as will appear from the appendix, have been very intelligently worked out, and a plant of considerable magnitude, equipped with specially designed machinery, was

* Filed in the committee's archives.

erected in Passaic, N. J., in 1891, where the manufacture of pantasote products has since been carried on commercially.

Referring to the mode of producing pantasote goods, the composition, or "gum," as it is termed in the manufacturers' description, when applied to the surface of the fabric, becomes thoroughly incorporated with the substance of the fabric upon which it is spread, adhering so tenaciously that it cannot be detached from the finished material. The products possess in high degree the qualities of flexibility and imperviousness to moisture, and notable freedom from any tendency to develop a "stickiness," or brittleness under ordinary conditions of temperature.

They are made to take any desired color by incorporating the same with the gum before it is spread on the fabric; and any desired grain in close imitation of the appearance of alligator, seal, morocco, hog skin, etc.; and any desired pattern in relief, as in the case of embossed leather. The appearance of these counterparts, and the excellent adaptability of the pantasote products for decorative effects are seen in the accompanying specimens, and leave nothing to be desired. The mode of making these surface impressions involves the use of powerful presses, the dies for which are made by an ingenious system of casting in bronze and iron from the original tissues, devised by Mr. A. E. Outerbridge, Jr., in which the impression is obtained in iron or bronze from the skins themselves. For this purpose dies 36 inches square have been made by the method referred to.

In respect also of "body," these products present great variety, from the "single texture" goods of light weight, suitable for book-binding, linings for trunks, bags, fancy leather goods, gossamer waterproofs, etc., to heavy materials suitable for upholstering and the like, in which the "body" is made of any desired thickness by a special method (protected by letters-patent), in which the "single texture" goods are backed with paper, or with a heavy cotton fabric, the two being made to unite by running between them a layer of specially prepared gum. This serves not only the purpose of sticking the two fabrics together, but also, as the manufacturers explain, "forms an impressionable

cushion, which receives and holds the embossed pattern, which being thus impressed in a solid surface, does not flatten or press out in handling or in the wear and tear of use."

The manufacturers claim for these products that they afford, notably, an admirable substitute for leather for most of the uses to which leather is adapted, and also that they possess some desirable qualities which leather does not possess. Reference is made particularly to the durable pliability of the pantasote products, under the continued influence of extreme heat and cold, and to the indifference of the products to water, fresh or salt, and to the fact that they may be scrubbed to remove dirt or grease, thus permitting of the use of the most delicate shades of color, which, in leather, soon soil.

There appeared to the investigating committee to be only one way in which these claims could safely be verified, namely, by the test of actual service, and, accordingly, this report has been deferred until sufficient time should have elapsed to obtain from reliable parties having the material in use, their testimony as to its fitness for various requirements of service.

The investigating committee, for this purpose, has placed itself in correspondence, during the last two years, with a number of manufacturers, builders and others having these products in use, and who may be assumed to be familiar with the merits of other leather substitutes, in order to learn from them how the pantasote products have stood the test of practical service.

Replies to these inquiries have been received from manufacturers of furniture, car builders, carriage builders, boat and ship builders, and others. These replies are uniformly favorable, and indicate that, as a substitute for leather for upholstery and carriage work, the pantasote products have undoubted merit, and that for these uses it is the best substitute for leather that has thus far been placed upon the market. The investigating committee has not been able to verify the claims of the manufacturers respecting the adaptability of their products for numerous other uses; but as

the above-named industries will probably consume much the larger proportion of the material, the committee does not deem it expedient to withhold its report longer for the purpose of including therein other and less important data.

The conclusion is warranted from the foregoing statement of facts, that the products collectively known by the name of "Pantasote" constitute a highly meritorious substitute for leather, for a number of the uses for which leather is adapted.

The Franklin Institute accordingly awards to the Pantasote Leather Company, of New York, the Edward Longstreth Medal of Merit.

Adopted at the stated meeting of the Committee on Science and the Arts, held February 5, 1896.

JOSEPH M. WILSON, *President.*
WM. H. WAHL, *Secretary.*

SAMUEL SARTAIN, *Chairman.*

THE DELANY SYSTEM OF MACHINE TELEGRAPHY.

[*Being the Report of the Committee on Science and the Arts, on the invention of Patrick B. Delany.*]

[No. 1896.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 1, 1896.

The Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating Delany's system of machine telegraphy, finds as follows:

The United States Patents submitted by the inventor, Patrick B. Delany, Nos. 510,006, 536,420 and 541,967, describe a perforator, a transmitter and a receiver. Patents are also pending for minor details.

The system, generally described, is a method of high-speed automatic transmission by a punched ribbon of paper, which makes and breaks an electric circuit, and the reception of the impulses upon a moistened ribbon of chemically

prepared paper, which is discolored by the passage of the current through it.

Other systems have preceded it, to which this general description applies, the details of which, however, are very different from the Delany system. The speed and reliability of all so-called high-speed systems have heretofore been limited by the static charge of the conductor and magnet coils. Many devices have been patented with the object of dissipating and neutralizing this charge, chief among which are the grounding of the conductor after every impulse, the reversal of the polarity of the current at each impulse, and the insertion of condensers in the circuit; all these methods have proven helpful, but not sufficiently so to make the systems commercially successful in operating a line, say, 1,000 miles long, at a speed of over 250 words a minute. When greater speeds are attempted, the static charge of the line following after the battery impulse when the circuit is opened continues the effect and closes up the spaces between the dots, or dots and dashes.

Mr. Delany, whose long experience and whose inventions in multiplex and cable telegraphy have made him thoroughly familiar with the methods of dealing with the static charge, has, in this system, devised a method of avoiding its effects, which is at once ingenious and valuable. In all prior systems the dots and dashes of the alphabet have been received in the same line of the paper, and the dots and dashes were used as their names imply. In the system under consideration, dots only are used. The dashes of the alphabet are distinguished from the dots by being received in a different line of the paper, and by being received in duplicate lines. The message will, therefore, be received in three parallel lines on the ribbon, the dots of the alphabet occupying the center line, the two outside lines showing the dots which represent the dashes of the alphabet, the same signal appearing in both outside lines. The dots and dashes, therefore, can never run together. As all the signals are dots, if two dots in the same line should run together by the action of the static charge, the comparative length of the record would show that two instead of one had

been transmitted. The advantages of dispensing with the dash are: first, less time is required to send the dot; and, second, the line does not accumulate so great a static charge by the brief connection to the battery in producing a dot as in producing a dash, while the impulse is sufficient for the signal. All spaced letters and long dashes, peculiar to the Morse alphabet, are excluded, the Continental alphabet being used.

The perforating apparatus for preparing the message for transmission consists of three telegraphic keys, representing a dash, a dot and a space, with steel punches operated by electro-magnets responding to the dot and dash keys, and a clockwork which moves the ribbon one step after the action of each punch, the space key being used after each letter and twice after each word. Such an apparatus is cheaply constructed, as compared with perforators which have a key for each letter of the alphabet. It can be operated at the rate of about twenty-five words per minute, which is about the speed of commercial telegraphy.

The transmitter is an apparatus consisting of a reel, upon which the perforated ribbon is wound, drums between which the ribbon is drawn, revolved by an electric motor, which is run at any desired speed, and contact brushes, or fingers, pressing upon either side of the ribbon, and meeting through the perforations to close the circuit; one pair on one line of perforations forming the dashes, and another pair forming the dots. This system of contact brushes ensures a perfect closing of the line, as the brushes are made of wire fibres, which are kept bright by the rubbing contact with the ribbon, and, when meeting through the perforations, interlace with each other. In all other automatic systems this contact has been made by a wheel, or brush, with the drum, and has resulted in much uncertainty.

The receiver of the system is an apparatus which consists of a reel with chemically prepared paper, moistened, wound upon it, pulleys or drums operated by an electric motor which can be run at any desired speed, and a recording stylus pressing upon the paper; also a device by which a local magnet stops the revolution of the reel as soon as

the message is finished. The stylus in this system has three points, one of which responds to positive currents and records the dots of the alphabet, and the other two, which are arranged on either side of the first, record in duplicate the dashes of the alphabet, and respond to negative currents. It will thus be seen that the battery current is reversed as often as a change is made from dashes to dots, and *vice versa*.

The committee charged with this investigation saw the apparatus in operation at the Franklin Institute, and afterward at the Philadelphia Bourse. Prior to that, one member of the committee saw it in operation over a commercial line 218 miles long, under the most unfavorable atmospheric conditions, the rain falling in torrents the entire length of the line. The conditions at the Institute and the Bourse simulated those of a commercial line in resistance and static capacity as nearly as that could be done by rheostats and condensers. In every instance the record received was clear and perfectly legible, the speed ranging from 940 words per minute over the commercial line to 2,000 words per minute over the artificial line.*

The investigating committee is of the opinion that the device of sending impulses of equal length into the line, whether representing dots or dashes; the receiving of these impulses in different lines on the recording strip, by the use of a suitable stylus and by the reversal of the polarity of the current; the invention of a contact brush, which ensures a perfect contact at any desired speed, and the many small details in the apparatus not specifically mentioned in this report, which, combined, produce a certainty in the results not hitherto attained in the art of telegraphy, and secure a speed in transmission and reception many times greater than by any other method, all constitute an invention of the first class, and are worthy of the highest commendation.

The Franklin Institute, therefore, awards the Elliott Cresson Medal to Patrick B. Delany for his system of machine telegraphy.

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* An illustrated description of the apparatus will be found in the *Journal of the Franklin Institute*, January, 1896.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, February 5, 1896.

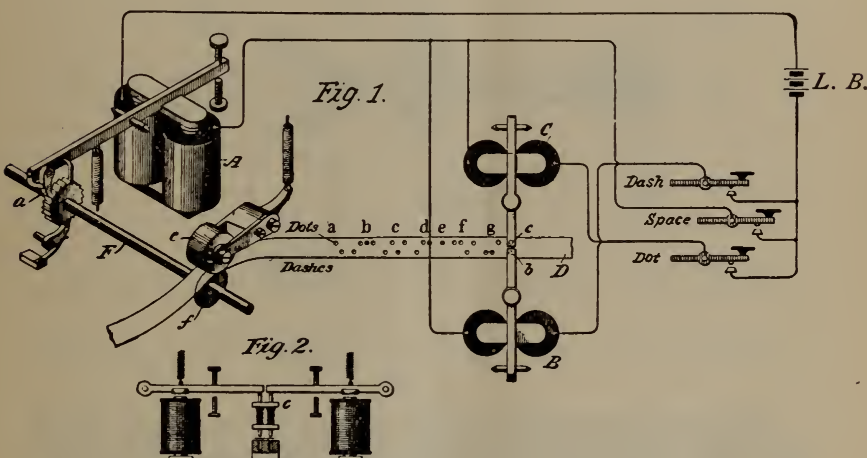
JOSEPH M. WILSON, *President.*
WM. H. WAHL, *Secretary.*

G. MORGAN ELDRIDGE,
Chairman of the Committee on Science and the Arts.

APPENDIX.

The following illustrated description will serve to give a clear impression of the details of the apparatus and mode of operation :

The Perforator, Fig. 1, comprises three keys—dot, dash and space key ; two electro-magnets for forcing the punches through the tape ; and a step-by-step tape-feeding device, also controlled by an electro-magnet.



The operation is as follows: The ribbon is perforated in two lines, the holes in the top line representing dots, those in the lower line dashes. The letters are made of combinations of dots and dashes, preferably according to the Continental Code. The lower contacts of the three keys are connected to one pole of the battery, *L. B.* The dot-key lever is connected to the punch magnet, *C;* the dash lever to punch magnet, *B;* and the space lever to space magnet, *A*. Obviously, but one key is pressed down at a time. The spacing magnet is in series with the dot and the dash magnets. To punch the letter *A*, the dot key is pressed down, magnet *C* forces its punch through the paper, and, at the same time, the lever of the space magnet is drawn down, and pawl *a* takes a new tooth in the ratchet wheel on shaft *F*. When the key is released and the circuit broken, the punch is raised out of the die and the strip is drawn a definite length by the sawtooth wheel *f*, and pressure wheel

e. Then the dash key is operated in the same way, after which the space key is touched, which provides a space between the letter punched and the one which is to follow. Thus, the space key is pressed down once after each letter, and three times after each word.

Perforating is no more laborious than working an ordinary Morse key, and the speed, with a little practice, will be fully up to the average of Morse transmission.

A side view of the punch magnets, their levers and punches, is shown in *Fig. 2*.

The Transmitter, Fig. 3, consists of a paper-pulling device, represented by roller, *R*, and the two pairs of wire brushes pressing toward each other above and below the tape. The top brushes are electrically one, and are connected to the line, *L*. The bottom brushes are insulated from each other, one being connected to the positive, the other to the negative pole of the main transmitting battery, *M B*. This battery is connected to earth at its middle.

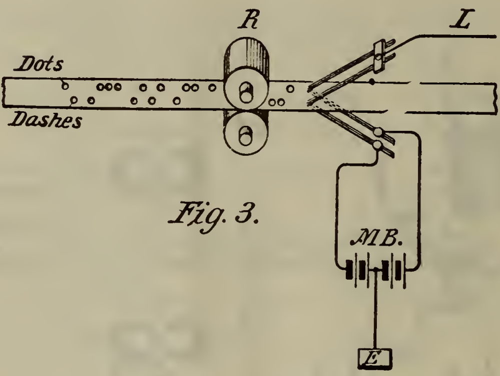


Fig. 3.

The paper tape separates the brushes; when a hole in the top line is drawn between the brushes, a positive impulse, representing a dot, is sent into the line. When a hole in the lower line is drawn between the other brushes, a negative current, representing a dash, is sent. In this manner all the dots and dashes on the tape are transmitted.

The brushes are made up of six wires each, so that six contacting points come together at each perforation. The ends of the brushes are kept bright and clean by the edges of the holes, and a pressure may be put on them which will insure electrical contact with the tape moving 30 feet per second, or at the rate of 8,000 words per minute, or over 2,500 impulses per second. An electric motor is used to pull the perforated tape.

As no dashes are sent, but only dots, which, owing to their position on the tape, *represent* dashes, the impulses are of uniform duration, and the line is not more heavily charged at one time than another; and consequently, the discharge is also uniform, and the signals on the receiving tape are correspondingly regular.

The Chemical Receiver.—The receiver is shown in *Fig. 4.* It comprises a wheel over which the chemically moistened tape is drawn under three thin iron wires which press lightly on top. The two outside wires are electrically one, and are connected to earth. The middle wire is insulated from the others, and is connected to line.

When the brushes of the transmitter drop into a hole in the dot line, a positive current is sent, and a dot is marked in the track of the middle wire of the receiver. When the transmitter brushes drop into a hole in the lower or dash line of perforations, a negative current is sent, and a dot is marked in duplicate on the receiving tape, one in the track of each of the outside wires. This impulse is but a dot in duration ; but as it is meant to represent a dash, it must have something to distinguish it from the dot signal ; therefore, the current is forked or divided on the receiving tape, so that all dashes are in the form of double dots, while the dots proper are single, and occupy the centre line on the tape. It will be understood that the chemically moist-

Fig. 4.

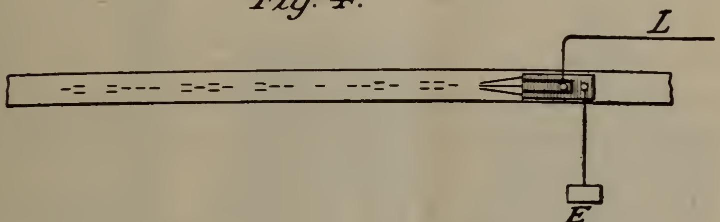


FIG. 5.

ened tape forms the circuit between the center wire and the outer wires of the receiver, or between the line and earth ; and that all positive currents come over the line and mark in the track of the middle wire, while negative currents come from the earth, and mark in the track of the forked contact, forming double dots, which are recognized as dashes.

In this way, no matter how bad the "tailing" may be, it is impossible to mistake a dot for a dash, or to connect them together erroneously ; neither is it necessary to have definition between successive dots or dashes. The length of the composite, single or double mark, determines at once the number of distinctive marks intended.

The specimens of record, *A* and *B*, seen in *Fig. 5*, illustrate this most important feature. *B* shows the word "telegraphy" with clearly defined individuality of each dot and dash. *A* shows the same word without any definition whatever, but, notwithstanding, the word to a practiced eye is just as plain in this form as the other.

THE PRENTISS AUTOMATIC CALENDAR.

[*Being the Report of the Committee on Science and the Arts on the invention of Henry S. Prentiss.*]

[No. 1888.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 29, 1895.

The Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the Prentiss Automatic Calendar, finds as follows:

This device is operated each midnight by the clock to which it is attached, and shows the day, week and month, adapting itself automatically to the varying lengths of the months, and accommodating itself to leap year, except for three out of four of the centurial years.*

It is impelled by a spring which has a capacity for running it for more than a year. To this spring is connected a train of gears, which impel a shaft carrying a card-rack indicating the days of the month. Continuing, the train of gears carries a fan by which the movement is regulated, which fan is normally held by a stop, detached by the clock at midnight.

The card-rack consists of sixteen wire loops, loosely connected to two discs on the shaft, each carrying on its points a card, which cards are numbered serially on one side from 1 to 16, and on the other side from 17 to 31, with the card between 30 and 31 blank. These cards revolve with the shaft, and are successively brought to a perpendicular position by a stop on the front of the machine. Parting from this stop, the card drops upon the card which preceded it,

* The subject of this report is covered by U. S. Letters-Patent Nos. 360,725, 417,742, 428,318, 428,319, 441,443, 458,490; dated, respectively, April 5, 1887; December 24, 1889; May 20, 1890; May 20, 1890; November 25, 1890; August 25, 1891.

the bottom of which is inclined forward by the other cards on the rack, with the result that the direction of the card is changed and the edge which was in advance, and nearest the shaft, now becomes the following edge, farthest from the shaft; and, at the next presentation of the card at the stop, the opposite face is exhibited, giving all the days of the month on the sixteen cards with great compactness and simplicity; showing a card of 2¼ inches in depth, bearing a

FIG. 1.

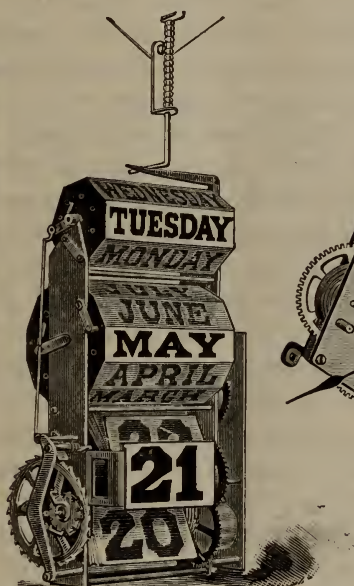


FIG. 2.

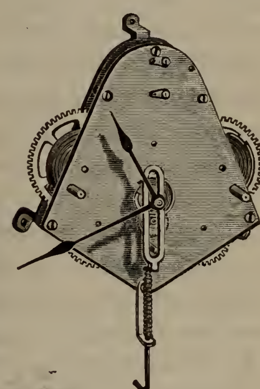


FIG. 3.

figure 2 inches in length, within a thickness of 4¼ inches. Geared to the shaft carrying the card-rack is the day-wheel, which makes one revolution each month, and is divided on its periphery into thirty-two spaces, thirty-one of which are armed with teeth which successively engage with a lever, which, when actuated by the tooth, rotates a cylinder carrying the days of the month, the forward movement of the card-rack shaft during this operation dropping a day card and substituting another The blank space on the day-

wheel corresponds in position to the blank card on the rack, allowing the shaft to rotate two day spaces, dropping the blank card as well as that showing 30, and leaving 31 exposed. On this shaft is also a cam, which engages with a lever connected to the cylinder showing the months. During the rotation of the shaft this lever is gradually drawn down by the cam until, on the first day of the month, the lever is released and, impelled by a spring, rotates by one point the cylinder showing the month.

On the face of the day wheel, near the blank tooth space, is a month wheel, divided on its periphery into twelve spaces, one for each month. At each revolution of the day-wheel the month-wheel engages with a projection of the frame, and is rotated one month space, and, accordingly, makes one revolution in a year. In the positions corresponding to the months having thirty-one days, its month-space next the edge of the day-wheel is inoperative, and the day-wheel records the thirty-one days. In the positions corresponding to the months having thirty days and to February, the month-space on the month-wheel projects even with and masks the tooth on the day-wheel next after the blank space, so that when the shaft is set in motion, and drops the 30 card and the blank card, the movement is continued and the 31 card is also dropped, showing next the 1 for the following month and changing the month.

For the purpose of regulating the apparatus for February and for leap year, there is, on the face of the month-wheel, a February wheel, having four projections, one of which, at each rotation of the month-wheel, engages with a projection on the face of the day-wheel and moves the February wheel one-fourth of a turn, this wheel making one revolution in four years. On the face of the day-wheel are two cams, corresponding in position to, and, when raised, making the teeth for the day-cards 29 and 30, so that, when these cams are in operation, the day-wheel moves continuously from 28 to 1. In three of the four positions of the year-wheel, when the February twelfth-space of the month-wheel is in action, both of these cams are raised by a pin on the year-wheel and are operative; but in the fourth position of this

wheel, the pin engages only that one of these cams which masks the 30 tooth, and the 29 card is consequently exhibited in its turn, the day-wheel passing thence to the 1.

The device is started in operation by tripping a lever at its top. To effect this automatically, without complicated mechanism in the clock, a wheel having a volute cam of two turns is placed on the shaft carrying the hour hand, and a looped rod passing over this shaft engages with this cam. Passing the end of this cam, which it is timed to do at midnight, the looped rod drops through a slot made for that purpose and strikes the lever. The slot extends through both turns of the volute cam; but the rod passes over it on a bridge of a loose piece, which then falls out of the way to allow the rod to drop through the slot. The spring on the lever is sufficient to sustain the weight of the rod, but yields under the blow, so that the action is but momentary. The applicant shows a device by which this operation is performed electrically, so that the calendar can be operated by the clock elsewhere than within its case.

Calendars adapted to be operated by clocks, and to register the month and the day of the month and of the week, with accommodation for the leap year, have been made heretofore; but the present one is exceedingly simple, very compact, positive in action, and readily adaptable to the movement of any clock. The whole apparatus occupies a space of but 9 inches wide, 14 inches high and 4½ inches deep, showing the month and the day of the week in letters ⅞ inch long, and the day of the month in figures 2 inches long. The arrangement of cards—by which sixteen cards, of 2¼ inches in height, show all the days of the month in figures 2 inches long, occupying a space in the clock-case of less than 4½ inches in depth and 5 inches in height—is specially commendable.

For the ingenuity displayed in condensing the mechanism accomplishing these results, the Franklin Institute recommends the award of the John Scott Legacy Premium and Medal to Henry S. Prentiss, of New York City, N. Y., for his Automatic Calendar.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, December 11, 1895.

JOS. M. WILSON, *President.*
WM. H. WAHL, *Secretary.*

SAMUEL SARTAIN,
Chairman, Committee on Science and the Arts.

Award confirmed by the Board of Directors of City Trusts.

APPENDIX.

Fig. 1 shows the complete calendar clock, *Fig. 2* the calendar movement and *Fig. 3* the clock movement. By reference to *Fig. 1* it will be seen that the day-of-the-week, month-of-the-year and day-of-the-month are all shown in full-sized letters and figures, which appear directly behind the sight-openings or windows in the case. They are sufficiently close to the glass of the windows to give a clear and desirable effect, the white margin of the mats adding considerably to the general result, and making the names and dates stand out in such a manner as to appear much larger than they really are.

Fig. 2 shows the calendar movement, and also the drop-rod and release-lever by which the calendar is started. The "21" is shown at the sight-opening, and on the starting up of the mechanism this card first drops down out of the way and lies close to the number "20," while a further revolution of the card device allows the "22" to drop into the position formerly occupied by the "21." The regulator-wheel and month-wheel may also be seen on the left of the cut.

Fig. 3 shows the clock movement, and also the cam and drop-rod which set off the calendar. The drop-rod falls sufficiently to strike the release-lever a sharp blow, and then rebounds and is held up and out of the way by its spring.

FOREST FIRES IN NEW JERSEY.

By JOHN GIFFORD,
Forestry Agent for the Geological Survey of New Jersey.

The question of fires in New Jersey demands immediate attention. It is the main cause of forest deterioration and its consequences, and of the impoverished condition of a large part of the State of New Jersey. There are very few stretches of woodland in this region which have not been thus affected.

The causes of forest fires may be classified as follows:

(1) Incendiarism.

(2) Carelessness.

(3) Sparks and hot coals from locomotives.

(4) Lightning.

The most serious fires are usually those which are purposely set, because set at the proper time and in the proper place. An incendiary bent upon mischief waits until the wood is dry and the wind in the desired direction. There are usually two motives back of incendiarism:

(1) Individual gain at the expense of another.

(2) Revenge.

A few years ago it was not uncommon for colliers to fire a wood in order to buy it cheaply. The charred wood is then only fit for charcoal. Owing to the decline of the charcoal industry and the abundance of charred wood in the forest, this is no longer profitable. Fires were set in meadowy regions to improve the grass for cattle. Savanna lands are still burnt for that purpose in regions where cattle are turned into the woods. Berry-pickers set fire to huckleberry bushes to improve the berry crop. In a couple of years, the young growth which follows bears larger and finer berries. Wood thieves, it is said, set fire to the brush and stumps to hide their tracks. There are many people living in the backwoods of New Jersey who own no woodland, but who gain a livelihood in a variety of ways out of woods which belong to other people. They are mostly berry-pickers, hunters and wood-choppers.

Fires are set out of spite. If a backwoodsman thinks himself wronged by a woodland owner, he "gets even" by touching a match to his woods. It is certain that for several purposes forest fires are set. Such fires do much damage, and the conviction of such incendiaries is difficult.

Woodland owners, during forest-fire season, feel insecure, expecting a fire at any moment. The incendiary may set a fire to injure an enemy, but the wind may suddenly change and many others may suffer in consequence. Several fires in Atlantic County were set last season in the same region several nights in succession.

Second in importance are fires caused by careless individuals. In clearing land, fires escape from burning brush. A large foreign element has come to South Jersey to clear farms. This increases the danger from fires while the land is being cleared. Tramps, hunters and boys, with camp-fires, lighted cigars and cigarettes, cause many fires.

Locomotives also are often blamed. It is certain that many fires have been set by sparks from the stack and hot coals from the grate. The greater number of the railroads are using some care. On some roads, engineers are cautioned, safety strips are cleared, and, in one instance, furrows have been ploughed along the road, and section-men usually endeavor to put out the fires which are thus caused. If engineers are careful, if the spark-arrester is not withdrawn or poked with holes, if coals are dumped in places prepared for that purpose, and if safety strips are cleared and furrows ploughed along the road, and section-men are watchful and willing, there is little danger from that source. It is certain that some railroads are using more precautions at present than woodland owners themselves.

Although not common, fires have been set by lightning. Certain species and solitary trees are more apt to be struck than others. There are several indications that a disastrous fire was set last summer in South Jersey, by lightning, which struck a solitary tree in a field of dry grass.

The effects of fire may be classified as follows:

(1) Destruction of timber and other property.

(2) Extinction of valuable species.

(3) Impoverishment of soil.

(4) Destruction of seeds and game.

(5) Consequential damage, by affecting industries dependent upon the woods, and by changing moisture, soil and climatic conditions, which are more or less dependent upon a forest cover.

The amount of damage depends, of course, upon the severity of the fire, which, in turn, depends upon the dryness of the wood, the force of the wind and the nature of the trees and underbrush.

Often everything above ground is killed. The charred

boles of hundreds of trees fall and rot in the woods. In low ground, after a fire, fresh green underbrush soon appears. High land recovers slowly, often remaining bare for many years. There is danger from fires about six months of the year. They are very destructive during the high winds in the spring, when there is little sap in the wood.

Dry leaves cover the ground, and many cling to the low oaks.

Certain trees are affected much more than others. This depends mainly upon the nature of the bark. Often, large pine trees appear to be but slightly affected by a ground fire, which burns the underbrush and leaves on the surface. Bark is a non-conductor of heat; but if the cambium, the active part of the tree just beneath the bark, is affected, the tree dies.

Even then, if it happens in spring, the tree appears to be recovering. Dormant buds in the trunk sprout, and fresh, green leaves are formed.

It is better to cut such trees at once, because they soon die. When the starchy matter in the trunk is exhausted, these sprouts wither and die, the tree is invaded by insects, rots and topples over. Even a pine log, if cut in the winter, sends out fresh shoots in the spring from dormant eyes. Even if the tree is not itself directly injured, its supply of nutriment and moisture is affected by burning the undergrowth.

The value of underbrush must not be underrated. Although it smothers young trees, it is useful to forests of larger growth. The amount of mineral matter which a tree absorbs is insignificant. Water is the essential element. In checking evaporation and retarding the flow, undergrowth is often necessary. But the smaller amount of dead wood in a forest the better, since it breeds many kinds of insects, some of which may invade the living trees. The material resulting from decay, however, enriches the soil, so that it is better to burn the dead wood which cannot be utilized. In that way the soil is enriched just the same, the insects are disposed of, and the underbrush is not seriously

disturbed. It is easy to see, therefore, how fire in a forest is often useful if wholly under control and directed by a forester.

In old pine woods, on upland, there is often little underbrush. The ground is covered with a thin layer of pine leaves.

Stump holes are common in such woods. When a pine tree is cut or burnt the stump decays and a hole of considerable size, with many ramifications, is formed. The ground is often riddled with holes from suppressed trees. These drain the water from the surface.

This, together with the slight shade of pines and lack of underbrush, accounts for the dryness of the soil and atmosphere in a pine woods. Many trees are soon affected by removing underbrush. The growth of a young oak grove can easily be retarded by trimming the lower limbs and removing the undergrowth.

Since one species is affected more than others, a kind of selection continues, which accounts for the peculiar distribution of trees in certain places. Thick-bark trees, and trees which produce a vigorous coppice growth, survive the longest. Pitch pines and oaks, therefore, predominate in South Jersey, while in isolated positions, protected from fires, a great variety of trees may be found. Certain plants, although covered with a thick bark, contain substances in the form of resin, oils and waxes, which are inflammable. Others contain substances which have a tendency to quench fire. The sowing of such plants along safety lines has been suggested to prevent the slow but destructive ground fires. The white cedar (*chamæcyparis thyoides*), the most valuable timber tree in South Jersey, and one of the most valuable in America, although growing in wet swamps, is often seriously damaged by fire.

The heat, although it may not burn, is often sufficient to kill the cedar. In unusually dry weather fires burn for many days in the bed of a swamp. It is often necessary to dig deep trenches in order to check its headway.

It destroys cranberry bogs in a similar fashion. For fear of fires, cedar is cut when fit only for rails, hop-poles and laths.

The soil is much impoverished by fire; this is the testimony of a large majority of farmers. The "life" is "cooked" out of it, as they say. The organic matter in the surface soil is often entirely burnt. The surface is bared so that the soil is soon completely leached.

Prof. F. H. Storer, in *Agriculture*, says: "Within porous soils nitrates are doubtless formed rather freely, and, as is well known, the nitrates are easily washed out from soils, and are liable to go to waste after every rain that is long continued. They are, in fact, leached out of the soil, and the manure from which they came rapidly wastes away. It is said to be a matter of old and familiar observation in Germany, that in sandy regions, in seasons that are particularly wet, the soil may finally be so thoroughly leached that it becomes unfruitful. When we consider the facts that nitrates are easily washed out of the soil, that they are absolutely essential to plant growth, and that they are continually produced, during the period of growth, from humus, by the action of nitrifying bacteria, we can appreciate the damage to light soils by fire. Land thus damaged needs very careful tillage and green manuring before it can produce a crop of consequence."

When a pine woods twenty years old is destroyed it may mean many years before the soil recuperates and seeds are again disseminated. Seeds on the surface are destroyed by fire. Some seeds are seriously affected by slight changes of temperature.

Also, many animals are destroyed. In the spring of the year the young are burnt in the nest. It is not uncommon to see many of the smaller animals chased before a fire. By preserving the forest, the animals dependent upon its fruits are preserved.

According to the statements of several seamen, the smoke and fog which the forest fires produce were a serious impediment to navigation along our coast last summer.

The total area burned over in South Jersey during the past season of 1895 amounts to not less than 197,000 acres. No improvement in the forest conditions of a country is possible as long as fires are allowed to burn without any

systematic preventive measures. With no protection whatever against incendiaries and individuals guilty of malicious carelessness, the owners of woodland are at the mercy of chance. In consequence, wood is usually cut just as soon as there is a market of any kind. Property in some towns in South Jersey is often endangered. Under such conditions capitalists hesitate to invest in woodland.

If a fire breaks out, it is seldom noticed until it has attained considerable size. The owner of the land coaxes and lures a few men to help him fight it. A fire often burns for some time, owing to the fact that competent men cannot be found. Many refuse to fight in the daytime. They wait until evening, when the fire is smouldering. Many fighters do more harm than good. These men are generally not paid. Often they are allowed to cut the dead wood. When this is refused, the land-owner is considered mean, and often has difficulty afterward in finding fighters. When allowed to cut dead wood, the privilege is usually abused. When a fire once gains headway in a dry woods, propelled by a strong wind, it is difficult if not impossible to check. Such work requires brave, skilful men, familiar with the region, and not chance men picked up here and there. The rapidity of spread of the fire depends, of course, upon the condition of the woods and the strength of the wind.

Although these fires are rapid, and although the sparks may fly long distances, a stream, spur of swamp, or even a road, are often sufficient to check their headway. Many fires which are very destructive burn for some time without being noticed.

The method of fighting is by back-firing. After the wind and other conditions have been noted, a party goes ahead to a road, which is always an excellent point of vantage, and burns back toward the fire. If possible, furrows are ploughed. The fires meet, and the force of the main body of fire is checked or diverted. Back-firing on another man's property to save your own, often causes trouble.

This much is certain about fires in South Jersey, that back-firing, in the proper way, is the most practical method of checking a fire, and that roads are excellent points of van-

tage. The clearing of roads for some distance on each side, and the burning of safety strips at the proper season, are important steps toward the prevention of fires. Were large tracts of woodland divided into sections, and each section surrounded by fire lines, there would be less danger. South Jersey is such a mass of woods, that when fire once gains headway, it travels for miles without meeting with opposition. Fires can be much more easily controlled in South Jersey than in a mountainous region. Sand, which is excellent material to fight with, is, fortunately, plentiful.

Proper policing by a mounted, organized, well-directed force of wardens, is necessary. The territory must be divided into districts of a certain size, irrespective of political divisions, with a warden to each district, with the woods, roads and clearings of which he must become perfectly familiar. He must be held responsible for that district. Stationed on an eminence, with field-glasses, one man can control a large area in South Jersey. It must be his duty to enforce regulations and to apprehend and bring to court all offenders. It must be his duty to keep a strict record of fires and other facts concerning the forests of his district. With a corps of twenty-five brave, skilful men, organized and under one head, fires can be reduced to a minimum, if not altogether stopped in the southern interior of New Jersey. These wardens must have the power to call on men to help them when necessary. These men must be under his control, and be paid fair wages for their work. Fighting fire is such a disagreeable and laborious task that there is little wonder competent men who will work for nothing are difficult to find. Experience in other countries shows that the presence of wardens has a strong educational influence. Twenty-five good men, for six months of the year, could be procured for $500 each. Allowing as much more for other expenses, $25,000 would cover the cost of such a force.

Considering the damage during the past season, there is economy in such a measure.

The prevention of fires is a difficult matter. It can be accomplished only by the co-operation of railroads, a large majority of the woodland owners and public-spirited citi-

zens, coupled with the aid of the proper kind of laws, backed with ample means for their enforcement.

To sum it all up, fires can be reduced to a minimum by removing the causes. Many of these causes are avoidable and will not exist if there is the proper kind of laws, with ample machinery for their enforcement. The few fires which are unavoidable can be extinguished in their incipiency if there is a warden present, who knows just what to do and how to do it.

THE CONDITIONS WHICH CAUSE WROUGHT IRON TO BE FIBROUS AND STEEL LOW IN CARBON TO BE CRYSTALLINE.*

BY W. F. DURFEE, C.E.

MR. CHAIRMAN AND GENTLEMEN:

I am announced to speak to you this evening upon the conditions which cause wrought iron to be fibrous and steel low in carbon to be crystalline.

In discussing this subject, the views which I shall present for your consideration are a few of the observations and conclusions derived from a somewhat intimate practical acquaintance, during the past forty years, with the manufacture and employment of both iron and steel; and I offer them as contributive to a correct understanding of the structural relations of these metals, or as indicative of their proper treatment in the course of manufacture and use.

The opinion is common among users of wrought iron and soft steel that the former has no carbon associated with it; and the belief is also prevalent that the minute percentage of carbon (0·10 to 0·15 of 1 per cent.) in the latter is at once the cause and explanation of the structural dissimilarity of these metals.

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*A lecture delivered before the Franklin Institute, January 31, 1896. Some of the matter of this lecture was presented in a lecture delivered by the author before the United States Naval Institute, at Annapolis, in 1887, and will be found published in the *Proceedings* of that Institute for that year.

Like many other popular opinions and beliefs, these are not established upon those hard, unyielding, azoic rocks of knowledge — well-ascertained facts — on which all true science is founded; for it is well known to investigators that the best fibrous wrought iron contains as much or more carbon than the average crystalline soft steel. As illustrating this fact, the following table* will be found of convincing interest.

PERCENTAGES OF CARBON IN SOME VARIETIES OF IRON AND STEEL.

SERIES OF THE IRONS.		SERIES OF THE STEELS.	
Description.	*Percentage of Carbon.*	*Description.*	*Percentage of Carbon.*
Soft puddled iron	trace*	Extra soft Fagersta Bessemer steel	0·085§
Armor plates	0·016†, 0·033†, 0·044†	Extra soft Dowlais Bessemer steel	0·135‖
Iron rail	0·09‡	Crewe boiler-plate steel, Bessemer process	0·22 to 0·24¶
Lowmoor boiler-plate	0·10‡	Locomotive crank-axle Seraing Bessemer steel	0·31‡, 0·49†
Staffordshire boiler-plate	0·19‡	Locomotive crank-axle, by Vickers, Sheffield	0·46*
Russian bar iron	0·272†, 0·340†	Rails and tires	0·30 to 0·50
Swedish bar iron	0·054†, 0·087†, 0·386†	Bessemer spring steel	0·45 to 0·55‡
Steely puddled iron	0·30 to 0·40‡	*Crucible Steel.*	
Iron made by Catalan process direct from the ore	traces†, 0·420†	For masons' tools	0·6*
Soft puddled steel	0·501†	For chipping chisels	0·75
Puddled steel rail	0·55‡	Crank-axle (by Krupp)	1·05‡
Hard puddled steel	1·380†	Gun (by Krupp)	1·18†
		For flat files	1·20*
		Forged Indian wootz	1·645†

* A. Willis. † J. Percy. ‡ A. Greiner.
§ D. Forbes. ‖ Snelus. ¶ F. W. Webb.

From this table it is evident that Lowmoor iron boiler-plate has more carbon than extra soft Fagersta Bessemer steel; that Staffordshire boiler-plate has over twice as much carbon as Fagersta steel; that some samples of Russian and Swedish bar iron have over four times as much carbon as the Fagersta steel; and, finally, that a sample of wrought iron made by the "Catalan" process (which produces exceptionally good wrought metal) had five times as much carbon as the Fagersta steel.

There can be no mistake in the foregoing figures, for they

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* From a paper read before the Institution of Civil Engineers, London, in April, 1875.

are the work of men world-famed for their intimate knowledge of the metallurgy of iron and steel, and unimpeachable as regards their conscientious skill as chemists.

Having thus shown you that the absence of carbon cannot explain the presence of fiber in wrought iron, it remains for me to lay before you the reasons for the peculiar structure of that metal.

Allow me, first, to endeavor to answer the question: "What is wrought iron?"

The following circumstances make the correct apprehension of this question difficult, viz.: (1) the way in which a mass of wrought iron is built up is not generally understood; and (2) the difference of its structure from that of a homogeneous material is not fully comprehended.

The term wrought iron is popularly supposed to designate a metal; but it is really the name of a mechanical admixture, which, at its best, consists of clusters of crystals (which may with propriety be regarded as compound crystals) of practically pure iron, separated from one another, as the result of the manipulative processes employed, by films or threads of an unavoidable impurity, called "cinder." By crystals of iron, I mean minute ultimate structural units of that metal, bounded by well-defined planes, whose intersections always form salient angles. A number of such crystals may cohere and form an aggregation, having bounding planes similar in outline and relative arrangement to those of any single crystal. Such aggregations or compound crystals vary in size and are often regarded as single crystals and spoken of as such, just as we speak of crystals of galena, or calcspar, when, as a matter of fact, the ultimate crystal of each of these substances remains undiscovered, and as undiscoverable as the boundaries of space. These large or compound crystals of wrought iron are, in themselves, practically homogeneous; that is to say, the ultimate crystals of which they are composed are not separated and kept apart by any foreign substance, but are as nearly in actual contact as the law of cohesion, in obedience to which they were formed, will admit. In the manufacture of wrought iron, the "pig," or other variety of cast iron, is first deprived, in a

more or less imperfect degree, of its carbon and other impurities, by what is known as the "puddling process." This process may briefly be described as consisting of four distinct operations, viz.:

(1) The melting of the "pig iron."

(2) The "boiling" of the melted metal in a bath of liquid "cinder" (composed mainly of silicate of protoxide of iron), until the iron (which, owing to its loss of carbon and other impurities, can no longer remain fluid at the temperature employed) begins to solidify in the form of small granules or crystals, which can be seen moving amid the boiling "cinder" like white-hot peas in a red-hot soup.

When the iron begins thus to granulate or crystallize, it is said to be "coming to nature."

(3) The collection, by the puddler, of these granules or crystals into distinct masses, called "balls," which may with propriety be regarded as white-hot sponges of iron saturated with liquid "cinder," which fills all their numerous accidental and irregular cavities.

(4) The "squeezing" or "hammering" of these "balls," while still at a welding heat, into more solid masses, which are called "blooms." These contain much less "cinder" and other impurities than the "balls," but are far from being uniform in structure; for, when the "balls" are "squeezed" or "hammered" (this last operation is often called "shingling") for the purpose of expelling the "cinder" and welding the granules or crystals of iron into a homogeneous mass, the attempt is never wholly successful; also, as the metal cools, the "cinder" quickly acquires a pasty consistency and flows with difficulty, and a large portion enclosed in the interior cavities of the "ball" is merely flattened or elongated. Hence, it will be seen that the "bloom" is composed of a compacted mass of granules or crystals of iron, separated from one another at numerous points by films, layers, or strings of "cinder" of very irregular dimensions, but which, notwithstanding, are mutually attracted with a greater or less degree of force, the minimum value of which is a measure of the cohesive strength of the mass.

Now, let us follow the "bloom" as it progresses towards the form of a commercial bar of wrought iron, and examine carefully the structural changes which take place during such progress.

When a properly-heated "bloom," or other similarly constituted mass of wrought iron, is subjected to the action of the hammer or rolls, the contained "cinder" endeavors to escape from its entangled mechanical alliance with the crystals of the iron, and in so doing, each particle thereof is driven into some line of least resistance, which is always finally located in a plane at right angles to the direction of the force acting upon the metal. In other words, if the bloom is rolled or forged into a rod or bar, the metal will be acted upon in two directions at right angles to each other,* and its compound crystals will be compressed in directions normal to the exterior surfaces of the bar, and at the same time extended in the direction of its length.

FIG. 1.

Thus the ends of adjacent crystals are forced towards each other, and the intervening "cinder" is compelled to move at right angles to the axis of the bar and to unite with the films or threads of "cinder" which have become established in parallel lines of least resistance along the flanks of the compound crystals, and at right angles to the direction of the force acting upon the bar.

Fig. 1 is intended to illustrate, on an exaggerated scale, this arrangement of the elongated compound crystals of iron with intervening films or threads of "cinder," the light spaces representing the iron crystals and the dark lines the

* In forging a bar it is the usual practice to turn it about its axis through an angle of 90° between the blows (or series of blows) of the hammer; and in rolling a bar it is commonly turned through the same angle between "passes" through the rolls.

"cinder"—the force of compression being supposed to act upon the bar in the direction of the arrow.

The direct consequence of the elongation of its compound crystals, and the effort of the intervening "cinder" to escape in the direction of least resistance while the wrought iron "bloom" is being forged or rolled, as before described, is the establishment of that structural peculiarity in the resulting bar, known as "fiber," which is one of the most conspicuous features of wrought iron, and one not found in any other variety of ferruginous materials.

When certain of the films or threads of "cinder" in a bar of "wrought iron" are so large as to be distinctly visible on its surface to the unassisted eye, they are called "sand seams" or "cinder cracks."

If its compound crystals are nearly pure iron, the bar can readily be bent cold without fracture, and if pulled asunder by a gradually augmented force, its fibrous texture is at once evident; but in case the compound crystals have chemically combined with some substance, such as phosphorus or silicon, which tends to diminish both the cohesive attraction between the ultimate crystals of which they are composed and the mutual attraction of the compound crystals, then the bar cannot easily be bent cold without rupture, and is said to have a crystalline fracture.

Notwithstanding this apparent absence of fiber, the mechanical structure of the bar is the same as before: that is to say, the "cinder" and elongated compound crystals are still arranged in lines parallel with the axis of the bar, and occasionally connected by branches at right angles thereto.

Whenever a "bloom" is subjected to a force of compression always acting perpendicular to the same plane, as is the case when it is rolled into a "sheet" or "plate," its compound crystals and accompanying cinder are each flattened and extended parallel with that plane, and the resulting "sheet" or "plate" has more of a laminated than of a fibrous structure, being built up of a number of leaves or strata of iron separated from each other by films of "cinder," which, when unduly thick at any point, cause defects in the plate, which are called "blisters."

The foregoing discussion of the structural characteristics of wrought iron brings to mind an important practical question, relative to the employment of wrought iron in construction, which has often been asked, viz.: Will a given sample of wrought iron, having a decidedly fibrous texture, become crystalline under the operation of a continued repetition of violent strains or shocks?

Doubtless many persons of large and varied experience in the use of iron will unhesitatingly answer this question in the affirmative.

The sailor who sees his chain cable (known to have been made of carefully selected, thoroughly worked and honestly tested fibrous iron) snap short, has no doubt about the metal having become crystalline, owing to lapse of time and rough usage.

The practical farmer, as he examines a broken trace or plow chain, is firmly of the opinion that the iron thereof had become crystalline by use.

The railway passenger who has fortunately escaped serious injury from an accident caused by a broken axle, is usually ready, even anxious, to testify, with emphatic confidence, that "the iron of the axle was crystalline and entirely unfit for the purpose for which it was used." Does a modern fiddle-string bridge go down under a passing train, plunging a whole community in mourning and sending a thrill of shivering horror through the land—among the various theories advanced to disguise the utter want of sufficient intelligently distributed material in the structure, is sure to be found that of the crystallization of the iron employed.

But let us return to our question. Can a bar of wrought iron of a pronounced fibrous structure be ruptured so as to exhibit a crystalline fracture? I answer, yes—in two ways:

(1) By a sudden application of a force of extension, commonly called a "jerk."

(2) By a prolonged repetition of a force of compression, sometimes called a "jar."

The first method of rupture may be said to consist of a transverse separation of the compound crystals of the bar,

as distinguished from a sliding of their interlocking flanks upon each other, as is the case when the rupture presents a fibrous appearance.

I have often seen crystalline fractures produced in truly fibrous iron. In the manufacture of iron rails (now practically an extinct industry) it was always considered desirable that they should be of a hard and crystalline texture as to their tops or "heads," but soft and fibrous in their bottoms or "flanges;" but however perfectly this distribution of metal was made, it was always possible to break a rail so as to show a crystalline fracture in its "flange." This was accomplished by making a slight "nick" across the "flange" (to determine the point of fracture), and placing the rail (flange down) in the "straightening press" on supports placed a short distance on either side of the "nick," and then putting in the "gag" *heavy* just over it—the result was almost always a crystalline fracture of the "flange"—in short, the elongated compound crystals were "jerked" asunder. But if the points supporting the rail were placed farther apart and the rail given an opportunity to yield considerably between them, then, if the "gag" was put in *light* a number of times in succession, the fracture of the "flange" would be sure to exhibit a fibrous texture, due to the fact that sufficient time had been given to break up the films of "cinder" between the flanks of the compound crystals and destroy their transverse cohesion, thus permitting them to slide apart and exhibit the appearance of disrupted fibers.

In *Fig. 2*, *A* represents a fracture of a bar of iron, such as would be made by a "jerk" or "jar." In this the compound crystals are separated transversely in or near the same plane, and from their appearance many would infer a total absence of fiber in the bar. In *B*, we see that the rupture was effected by an apparent longitudinal sliding of the strings or strands of compound crystals upon each other, in consequence of a prolonged "pull;" but such a movement of these strings or strands cannot possibly take place until every string or strand of crystals is first ruptured transversely; but this does not occur in or near the same plane,

as in the case of *A*, but each string or strand is transversely ruptured at a point some distance from the rupture of the neighboring string, or strands, and the final separation of the interlocking strands of crystals taking place by a sliding of the flanks of the aggregation of strings of crystals belonging to one part of the bar; along those belonging to the other part, very much in the same way as the longitudinally interlocked fingers of the two hands are separated by a sliding movement, on applying a tensile strain in the direction of their length for that purpose. The language seems to lack words to designate and distinguish these two methods and kinds of rupture; and if I may be permitted to coin a pair of words to fit the observed conditions, I will say

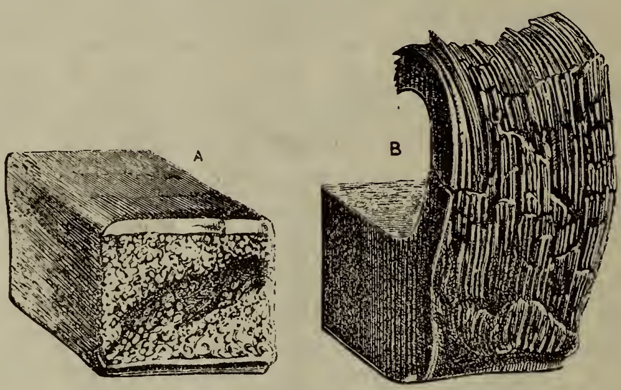

FIG. 2.

that the simple transverse crystalline fracture, *A*, is a homoplanic rupture, and the complex fibrous separation, *B*, is a heteroplanic rupture.

We are indebted to a not uncommon accident to which the hammer-bars of a peculiar type of steam-hammer are liable, for an excellent illustration of the second method of producing a crystalline fracture in fibrous wrought iron, the result of the repeated action of a percussive force of compression. In *Fig. 3* is represented, at *A*, the bar of such a steam-hammer. As before stated, there exists, in a bar of fibrous iron, films of cinder between the ends of its elongated compound crystals (as shown exaggerated in *Fig. 1*). These, from the nature of their formative process, cannot possibly

be of uniform thickness. This, considered in connection with the fact that the greatest force of the percussive action per unit of area of any cross section of the hammer-bar is exerted upon a section made by a plane cutting the bar at right angles immediately above its head, justifies the belief that at or near this point fracture will be most likely to occur. It is also evident that the percussive action of the hammer will have more destructive effect upon thick than upon thin films of "cinder;" while, at the same time, the force of cohesion between the ends of adjacent compound

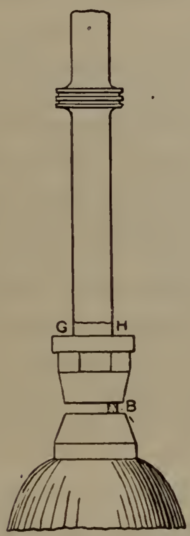

FIG. 3.

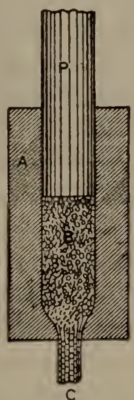

FIG. 4.

crystals will be diminished in some inverse proportion to the thickness of the films of "cinder" between them. It, therefore, seems exceedingly probable that the fracture due to continued percussion will take place, if not in the plane above-named, yet in one very near to it, in which the "cinder" films chance to be of greater thickness than those in that plane; and, as a matter of fact, fractures in such bars are usually within a few inches of the point where the bar enters its head, as at *G*, *H*, *Fig. 3*.

The particular point in the circumference of such a hammer bar where the imminent fracture first appears is

often determined by the manual peculiarity of the hammer-man. A left-handed man will incline his work to the left, and a man who is right-handed will be likely to use the right side of the anvil more than the left. In this latter case, the work *B* (*Fig. 3*) will tend (whenever it is in the position shown) to produce a jarring tensile strain at the point *G*, and a jarring compressive strain at *H*; and if the work is placed on the center of the anvil, the strain upon the "cinder" in the plane *G*, *H*, will be uniformly distributed as a jarring compressive one, and as the work is shifted to the left side of the anvil, the character of the original strains becomes reversed, that at *G* becoming a jarring compressive strain, while that at *H* has changed to a jarring tensile strain. These irregular changes of direction and force of the jarring strain cause the beginning of a fracture at that side of the bar where the film of cinder is the thickest, and it gradually extends across until finally the bar is "jarred" asunder. The progress of rupture in the way just described is not usually rapid, for I have known of a hammer-bar being used over two years after the first manifestation of incipient separation before the actual rupture occurred, which then took place through films of "cinder" between the ends of the elongated compound crystals of the bar, thus exposing those ends, and exhibiting what is called a crystalline fracture.

It is a well-known fact that wrought iron is improved in strength by repeated working. This may be accounted for thus: In the initial heating and shaping of the metal, its crystals were left with a comparatively thick film of cinder between them; but, by each successive re-working, the crystals of metal are driven into closer order; some of the intervening "cinder" is expelled, and what remains is very much reduced in thickness, so that the cohesive attraction (whatever that may be) between these crystals, having less space through which to act, acts with augmented intensity.

It is well to remember that when we speak of "less space" in describing the contiguity of crystals of wrought iron, we are dealing with a very small dimension, in fact, one very near neighbor to the infinitesimal.

The mechanical action which takes place as the result of shock, in the films of "cinder" which separate the compound crystals in a bar of wrought iron, is believed to be somewhat as follows: Each individual "jerk" of extension or "jar" of compression slightly (this word must be taken as meaning in this connection, almost the minuteness of negative infinity) disarranges the molecules of the thickest film of "cinder" in the immediate vicinity of that section of the bar in which the shock is the most powerful, and, as the result of this disarrangement, the crystals of iron cannot be brought as close together under the operation of cohesive attraction, as they were before the disturbing shock, and as shock after shock is experienced by the bar, its crystals of iron become further and further separated, and their cohesive attraction enfeebled, until finally it is not sufficient to resist the shock which ruptures the bar. This view may be said to be pure speculation; but if it accounts for the facts observed, it is quite as justifiable as the belief in the interstellar ether of astronomical physics, or of the ultimate atoms on which the modern science of chemistry is founded. No person ever saw, heard, smelt, tasted, felt, weighed or measured atom or ether; and yet, upon their recognition as absolute entities depends the explanation and comprehension of celestial and material phenomena, whose existence is certain, and whose importance cannot be overrated.

Very much of the difficulty of correctly comprehending the structure of the material of which we have been speaking may be eliminated by recognizing the fact that what is commonly called wrought iron is not, in its entirety, really iron; and remembering that the only way in which *pure iron* can be obtained is by electrolysis, a process, I need hardly say, commercially impossible for all practical purposes in the present state of our technical knowledge.

The belief in the so-called crystallization of fibrous wrought iron as the result of prolonged use is, I think, altogether a mistaken one, and I am clearly of the opinion that the crystallization observed in the case of any particular fracture existed just as we see it exposed in the break at

the time the metal was given the shape it had when ruptured. After a bar of distinctly fibrous wrought iron has been subjected to multitudes of sudden "jerks" of extension or "jars" of percussive compression, the "cinder" in some cross section of it (in which this impurity is slightly thicker than elsewhere) gets broken up, cohesion is destroyed, and the bar breaks with a crystalline fracture.

Time passes, and, though I could fill the fleeting hour with talk about iron, yet in this lecture, as in the field of mechanical construction, it is now fitting that iron should give place to steel.

What is steel? To the many answers to this frequently-asked question I will venture to add one more, viz.: steel is iron freed from mechanically-mixed impurities (such as "cinder," etc.), by a melting process, during which there is combined with it chemically a small percentage (not large enough to prevent the metal being forged or rolled) of other impurities, introduced for the purpose of modifying its strength, hardness, elasticity or ductility, in such way and degree as to adapt it to the particular use to which it is to be applied. In short, while wrought iron is iron having (as the unavoidable result of the methods employed in its manufacture) its impurities mechanically mixed therewith, steel is iron having (as the result of the adoption of appropriate manufacturing processes) its impurities chemically combined therewith.

Foremost among the substances chemically combined with iron to convert it into steel, is carbon. When this element exceeds 0·12 to 0·15 of 1 per cent., it begins to confer a hardening property upon the iron with which it is associated, but, at the same time, it does not destroy the forgability of the metal until its proportion attains about 1·5 per cent. Other substances have been added to iron in connection with carbon, for the production of special qualities of steel, and of these manganese, nickel, aluminum, chromium, tungsten and titanium are the most important.

I cannot, at this time, attempt to describe at length the various processes employed in the manufacture of steel, or

even its various properties and uses, but must confine my remarks, as intimated in my subject, to steel "low in carbon" —that is to say, to steel in which the carbon percentage is so low as not to confer a hardening property upon the metal; in fact, to steel in which carbon is present in as small proportion as in most wrought irons, or even smaller, and to certain practical details of its manufacture which I deem of especial interest and importance.

The most notable distinguishing difference between "low steel" and "wrought iron" is the want of "fiber" in the first-named material and its presence in the last. *Fig. 4* illustrates a method of showing by experiment the character of the structural difference between a bar of wrought iron and one of a homogeneous material such as low steel. In this figure, let *A* be a vertical section of a cylinder provided with an accurately fitted plunger, *P*. The space, *B*, below this plunger, we will suppose to be filled with small, irregular fragments of lead, whose surfaces are covered with a coating of oxide of lead. If, now, sufficient force be applied to the plunger, *P*, the lead will be forced out of the hole in the lower end of the cylinder in the form of a rod, *C*, and every fragment of lead will have become more or less elongated, but will be prevented from actual metallic contact with adjacent fragments by a film or thread of oxide of lead. In this experiment, the elongated fragments of lead correspond to the extended compound crystals of iron before named, and the oxide of lead occupies the same relative position in the rod of lead as the "cinder" in a bar of wrought iron. If, now, in place of the fragments of lead, we place in the space, *B*, a solid mass of that metal, then, on applying adequate force to the plunger, *P*, there will be forced through the hole in the bottom of the cylinder a rod of lead, whose structural difference from the former rod, made from the oxide-covered fragments, is closely allied to that subsisting between a bar of "low steel" and one made of the cinder-coated compound crystals of wrought iron.

All steel in our day (save the comparatively unimportant product called blister steel) is made by some process involving melting and casting; and, although the various methods

employed all practically free the metal from an admixture of "cinder," and in consequence tend, so far as the elimination of cinder is concerned, to produce a homogeneous crystalline structure; still, owing to defects inherent in the method of casting—and oftentimes in the chemical constitution of the metal itself—the ingots of steel are too often far from homogeneous. In fact, their structure may be such that, when hammered or rolled, the resulting bar, although destitute of cinder, may, nevertheless, show evidences of fiber.

I will endeavor to explain how this appearance is produced. If we break a large ingot of mild steel (say from 12 to 15 inches square) at right angles to its length, and examine the fracture, we shall find, at a distance of from $\frac{3}{4}$ inch

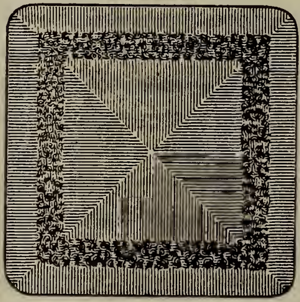

Fig. 5.

to 2 inches from its sides, a collection of cavities or "blow-holes" (as they are commonly called), which are of an irregular spheroidal form, and of variable size, the largest seldom exceeding $\frac{1}{2}$ an inch in diameter. These holes are separated from one another by partition walls of irregular thickness, and in most instances are coated on their interior surfaces with films of a more or less iridescent oxide of iron. *Fig. 5* will serve to give an idea of such a fracture as has been described.

When such an ingot is forged or rolled into a bar, it is seldom or never subjected to a "welding heat;" hence, the "blow-holes," even if it were possible for their sides to come in close contact, would not weld and become as solid as the homogeneous parts of the ingot; but, as a matter of fact, the

sides of these cavities rarely do come in actual contact, for they are held apart by the presence of a gas or mixture of gases, of whose character and pressure I shall speak later.

The forging or rolling flattens the blow-holes and also extends them in the direction of the length of the bar, the division walls between the "blow holes" being extended also, the effect being, when the "blow-holes" are numerous, to produce an apparent fibrous structure in the bar, and the more numerous the "blow-holes," the finer and more "silky" the fiber. In case the "blow-holes" are large, and the partitions between them comparatively thick, they will—when the ingot is drawn into a bar—form seams of variable length and depth, as they chanced to originate from larger or smaller holes.

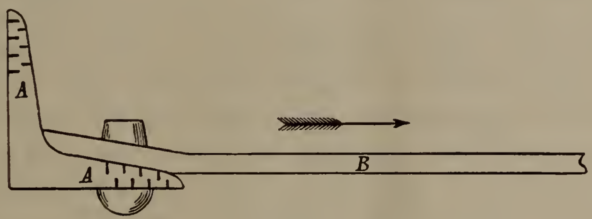

Fig. 6.

Such a state of structural affairs in a bar might not have much influence upon its ability to resist a tensile strain; but if such a bar were subjected to compression, it is easy to see that it would yield unequally, and much sooner on the side having the greatest number of such seams. But it is when such a bar is subjected to a transverse strain tending to pull it apart in a direction at right angles to its length, that these seams, whose progenitors were blow-holes, are the most injurious.

Take, for example, an "angle-iron" made from such an ingot. It is not at all improbable that the "seams" would be so arranged in the flanges (as at *A*, *A*, *Fig. 6*) as nearly to separate them into a series of rods held together transversely by occasional ligatures of metal. Now, if such a bar be punched or drilled through the "seams," and another bar, *B*, be riveted to it (as shown in the figure), and

the riveted structure be now subjected to a strain in the direction of the arrow, it is self-evident that the "angle-bar" would be much more likely to be pulled apart transversely through the rivet hole than if it were made of a homogeneous material.

There has been a great deal of speculation in regard to the origin of the array of "blow-holes" found in ingots of soft steel. Some have supposed that they were caused by gases dissolved in the fluid steel (very much as carbonic acid is dissolved in water), and that, at the moment of solidification, these gases separated from the mass of the metal, and arranged themselves in the order in which they are found, that of a hollow square (in the case of a square ingot), whose sides are parallel with those of the ingot. Others have asserted that oxide of iron is present in the fluid metal, and that this being reduced by the carbon in the steel, carbonic oxide, carbonic acid, or both are set free, which, being unable to escape before the steel solidifies, produces the aggregation of cavities we are considering. This theory may, in a measure, be true in the case of steel containing oxide of iron but we know that good metal does not contain oxygen, and if the holes were in any great degree due to the reaction mentioned, they would be likely to be uniformly distributed through the mass of the ingot, and not confined, as is the fact, to a well-defined zone; moreover, but a very small percentage (about 2 per cent.) of the gaseous contents of the blow-holes is found to be oxidized carbon.

Other suggestions, more or less occult, hypothetical, and ingenious chemical and molecular considerations, have been made; but all fail to account satisfactorily for the symmetrical arrangement of the "blow-holes" observed.

My own explanation of the formation and peculiar distribution of these cavities is a purely mechanical one, which I will now endeavor to make clear.

It is a well-known fact that a vertical stream of any liquid descending freely through the atmosphere drags along with it, by frictional contact, a notable quantity of the air, or of any other gas that may be in its immediate vicinity.

This fact, centuries ago, was taken advantage of in the construction of the blowing apparatus, called the "trompe," used for furnishing the blast for the forges of Catalonia.

This apparatus consists of a vertical pipe, *P* (usually of wood), whose height is determined by that of the head of water at the locality of the forge; the upper end of this pipe passes through the bottom of the wooden race-way, *R* (*Fig. 7*), and is closed or opened by the movable conical plug

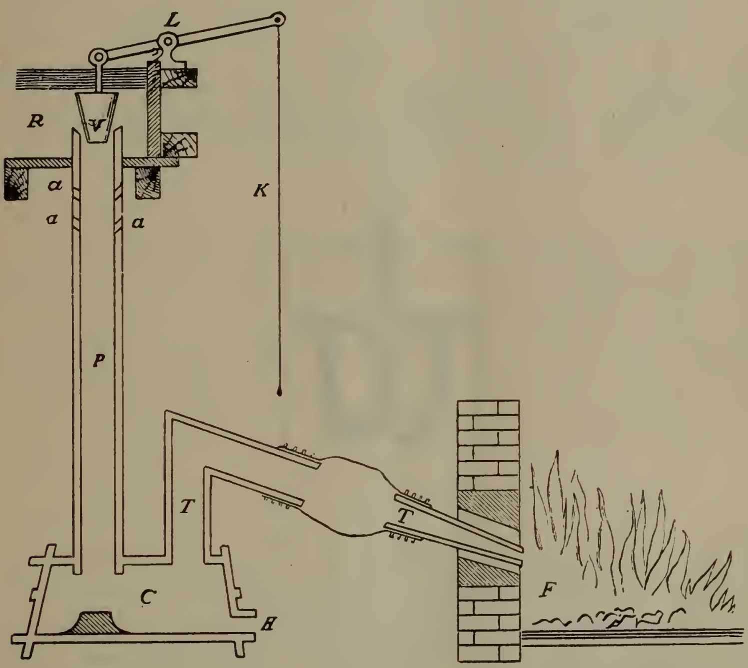

FIG. 7.

or valve, *V*. Below the bottom of the race-way, *R*, there are several inclined apertures, *a*, *a*, *a*, made in the sides of the pipe, *P*. These are for the purpose of admitting air, which, when the valve *V* is raised, is drawn in by the descending column of water, and, mixing therewith, is carried downward and discharged thereby into a receiving chamber, *C*. Here a separation of the air and water takes place, the former passing through the tuyere pipe, *T*, *T*, to the forge-fire *F*, the latter escaping from the receiving chamber

through a hole in its side at *H*. The volume and pressure of the blast supplied can be regulated within certain limits by raising or lowering the valve, *V*, by means of the cord, *K*, acting through the lever, *L*.

Now let us see how the principle of the "trompe" is concerned in the casting of an ingot of steel. Let the beaker, *B* (*Fig. 8*), represent an ingot mould, and the descending stream of water, *W*, a stream of molten steel. It will be seen that the stream *W* (for illustrative purposes regarded as liquid steel), carries with it a large volume of air, which, in its endeavors to escape, turns, and in the form of globules or bubbles takes an upward direction parallel with the sides of the beaker (representing the ingot mould).

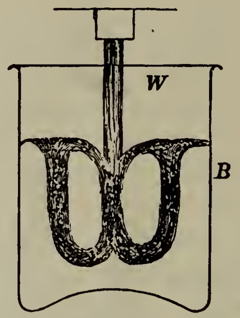

FIG. 8.

On the stoppage of the stream, *W*, all this air immediately escapes from the water, leaving it as free from air bubbles as water usually is; but if, during the filling of the beaker, the water therein were rapidly frozen (the progress of the congelation being from the sides towards the center), it is evident that the ascending bubbles of air would be entangled in the ice as it formed, and we would have finally a vesicular mass or ingot of ice, quite similar, as regards its method of formation, to the ordinary ingot of steel.

Another illustration may make the formation of vesicles in steel ingots still more clear. If, in place of water in the preceding experiment, we substitute mucilage, or any other fluid of similar consistency, we approach much nearer

to the actual conditions which exist in the casting of a steel ingot; for the steel, as ordinarily melted, is never as fluid as water, but approximates more nearly in mobility to the character of mucilage. As, then, the stream of mucilage descends, it will be observed that it carries with it air, in the same manner as the stream of water; but that, owing to the viscosity of the fluid, the air bubbles rise through it more slowly and escape with greater difficulty, and that some of them, as they approach the surface, are again dragged down by the central descending current. Hence, there is a much larger collection of bubbles of air in the mucilage than there was in the water, and consequently, if the mucilage were solidified at the moment the bubbles ceased descending, we should have a much more vesicular mass than in the case of the frozen water in the last experiment.*

In comparing the foregoing experimental illustrations with the actual conditions which exist during the casting of an ingot of steel, we find an ingot mould of cast iron (corresponding to the beaker), which is filled by a rapidly descending stream of molten steel (corresponding to the water or mucilage), not as liquid as water, but more nearly of the consistency of mucilage. We also find that this stream carries into the imperfectly fluid mass of steel, which rapidly fills the ingot mould, a large volume of air, which attempts to rise and escape from the rapidly cooling and solidifying mass of metal in precisely the same way as the bubbles of air endeavored to escape from the water and mucilage in our two illustrative experiments. But we find another condition present in the case of the molten steel, that did not exist in either experiment, viz.: the fact of a high temperature in the fluid metal. If we examine this condition, we shall readily discover that it has a very important influence both on the size and number of the vesicles formed in the ingot of steel; for it is a well-known fact that dry air, for each 480° F. increment of temperature, increases its bulk by the amount of its original volume. Now,

* These experiments were shown to the audience by the lecturer.

as the fluid steel is at least of the temperature of 3,300° F., dry air introduced in the manner illustrated would be so expanded as to occupy seven times the space in the ingot that it did in the atmosphere.

There is, however, yet another fact that tends still further to augment both the size and number of the so-called "blow-holes" which we are considering. It is a well-known practical condition that the air in the immediate vicinity of steel casting pits is far from being dry. The large quantity of water used for cooling ingot moulds, and for other purposes, keeps the atmosphere surrounding both casting-ladle and ingot-mould in a very moist state, and it is certain that all such vapor-laden air carried into the molten steel would increase in volume for a given increment of temperature very much more than dry air, and would, therefore, correspondingly increase the size and number of the "blow-holes." Furthermore, this vapor of water does not act to this end altogether through its expansion under the influence of heat, for some, if not all of it, is decomposed by the high temperature, and its oxygen, together with that of the accompanying air, is absorbed by the walls of the cavities. This produces the iridescence observed, and leaves in the "blow-holes" an atmosphere composed mainly of hydrogen and nitrogen; and it is not at all improbable that in many cases this decomposition of the watery vapor does not take place until the steel is so far solidified as to prevent the walls of the cavities yielding to any great extent, and, under such circumstances, the gases named would be under a very considerable tension.

This view is confirmed by the investigations of Prof. F. C. G. Müller, of Brandenburg, who found that the mean composition of the gases in the "blow-holes" was:

	Per Cent.
Hydrogen	79
Nitrogen	19
Carbonic oxide	2
	100

and that their average pressure was 120 pounds per square inch. That under favoring conditions they may

have a much larger pressure is evident; and furthermore, that the sum of the pressures in all the "blow-holes" of any cross-section of an ingot of steel may originally be very considerable, and that after the cavities have been reduced in size by hammering or rolling, the sum of these pressures will be largely augmented.

Let us now examine the influence of these confined gases upon the steel after the ingot has been rolled into a bar, by considering a supposititious case—the most favorable one possible—and one not at all unlikely to occur in practice, as regards one or more blow-holes. We will suppose that we have an ingot of steel 15 inches square and 5 feet in length, and that this ingot has the usual zone of "blow-holes" grouped as before described, and that every cube of $\frac{1}{2}$ inch within this zone has a blow-hole within it, or 60,000 in the entire ingot, or 500 in any cross-section through the $\frac{1}{2}$-inch cubes. We will take, for our investigation, a spherical "blow-hole" $\frac{1}{4}$ inch in diameter, the area of whose largest cross-section is ·04908 of a square inch, and whose capacity is ·00818 of a cubic inch. If, now, our ingot be rolled down to a bar 1 inch square, it will be obvious that each side of this bar will be $\frac{1}{15}$ of that of the ingot, and that the area of its cross-section will be $(\frac{1}{15})^2$ or $\frac{1}{225}$ of the original cross-section of the ingot, and that the diameter of the $\frac{1}{4}$-inch "blow-hole" will have been reduced to $\frac{1}{15}$ of its original size, or

$$\frac{\cdot 25}{15} = \cdot 01666$$

of an inch, and the area of its cross-section will have become

$$\frac{\cdot 04908}{225} = \cdot 00021813$$

of a square inch. But if the original pressure of the gases in the blow-hole (120 pounds per square inch) be unchanged in the bar, their volume must remain unchanged, and this is only possible by a change of form in the "blow-hole" under the operation of rolling, from a sphere of $\frac{1}{4}$ inch diameter to a cylinder of ·01666 of an inch in diameter, and of sufficient

length to hold the original volume (·00818 of a cubic inch) of the gases. The length of such a cylinder will be

$$\frac{\cdot 00818}{\cdot 00021813} = 37{\cdot}5$$

inches. But as the diameter of this cylinder is ·01666 of an inch, the area acted upon by the gases within it to tear it

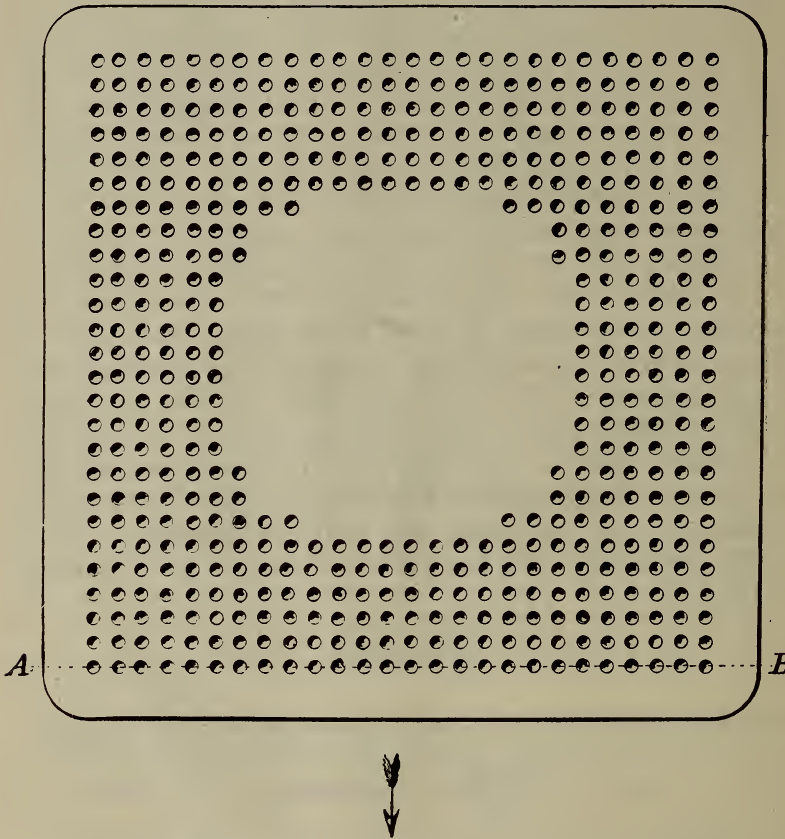

Fig. 9.

asunder longitudinally is equal to $37{\cdot}5 \times \cdot 01666 = \cdot 62475$ of a square inch, and as by our supposition there are 500 holes in a cross-section of the ingot, we shall find at least 26 in the outside rows of the zone of blow-holes, and, therefore, we shall have in the 1-inch square bar the same number such

as we have described above; hence, the total area on which the pressure acts to effect the longitudinal disruption of the bar within the space of the length of one such row of cylinders is ·62475 × 26 = 16·25 square inches, which, multiplied by 120 pounds per square inch, gives us 1,950 pounds as the disruptive stress. To sustain this, we have what remains of solid metal in a section (of the length of the cylinders) made by a plane parallel to the side of the bar (corresponding in the bar to *A B* in the ingot, *Fig.* 9), and including the axes of the 26 cylinders above named, or 37·5 — 16·25 = 21·25 square inches. Dividing the disruptive stress by this, we have

$$\frac{1{,}950}{21 \cdot 25} = 91 \cdot 76$$

pounds per square inch. Now, let us compare the area on which pressure acts in the ingot with that on which it acts

FIG. 10.

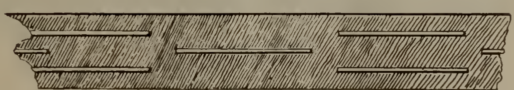

FIG. 11.

in the bar. The area of the largest cross-section of a spherical "blow-hole" ¼ inch in diameter is ·04908 of a square inch, and we have shown that the area of a longitudinal-section of one of the above-named cylinders is ·62475 of a square inch, or 12·7 times the area of the cross-section of the original "blow-hole;" or, in other words, the process of rolling the ingot down to a bar 1 inch square, by transforming the original "blow-hole" from a sphere to a cylinder of equal volume, has multiplied the area upon which disruptive pressure acts 12·7 times.

The foregoing calculation is based upon the assumption that the twenty-six cylinders are arranged with their ends abreast (as per *Fig. 10*), which could only happen when the

"blow-holes" were symmetrically arranged in the ingot. It is also possible that these cylinders may be disposed as per *Fig. 11*, in which case there would be but half the number of cylinders within the area of 37·5 square inches, and the sum of the areas of their longitudinal-sections will be ·62475 × 13 = 8·125 square inches; which, multiplied by 120 pounds per square inch, gives us 975 pounds as the disruptive stress. To sustain this we have 37·5 — 8·125 = 29·375 square inches of metal, which is subjected to a strain of

$$\frac{975}{29{\cdot}375} = 33{\cdot}15$$

pounds per square inch.

There is still another arrangement of the cylinders which perhaps is more likely to occur than either of the others. (See *Fig. 12.*) By this the strain upon the metal will be between the figures given for that in *Figs. 10* and *11*, or about 65 pounds per square inch.

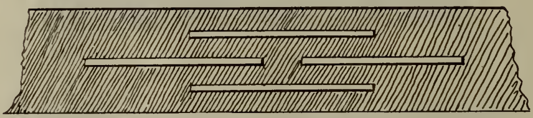

FIG. 12.

Now let us examine the disruptive stress on a transverse section of our 1-inch square bar. By our original supposition there must be in such a section 500 cylinders having an area of cross-section of ·00021813 each, or a total area of cavity of ·00021813 × 500 = ·109 of a square inch, which, multiplied by 120 pounds per square inch, gives us 13·08 pounds for the disruptive stress. To sustain this we have 1 — ·109 = ·891 of a square inch of metal, which is subjected to a strain of

$$\frac{13{\cdot}08}{{\cdot}891} = 14{\cdot}68$$

pounds per square inch.

It will be observed that the foregoing calculations have supposed that the volume and pressure of the gases remain unchanged under the operation of rolling or hammering,

which is the most favorable condition possible in the bar when "blow-holes" filled with gas are present in the ingot from which it is rolled. But it is not at all probable that so favorable a condition will uniformly be present in the bar; for it is much more likely that many of the cylinders will, under the stress of rolling or hammering, be more or less compressed, closed up, or shortened. For instance, if the diameter of one of these cylinders were reduced one-half, the pressure within the cylinder would become four times that of the initial pressure, or $120 \times 4 = 480$ pounds per square inch, which would act over an area of

$$37{\cdot}5 \times \frac{{\cdot}01666}{2} = \frac{{\cdot}62475}{2} = {\cdot}31237$$

of a square inch, and which, multiplied by 480 pounds, would give 150 pounds disruptive stress. If we suppose that there are 26 tubes thus reduced in diameter, we will have $150 \times 26 = 3{,}900$ pounds as the total disruptive stress on the whole number of tubes. To sustain this we have 37·5 square inches minus the sum of the areas of the longitudinal-section of 26 tubes (${\cdot}31237 \times 26$), $8{\cdot}12162 = 29{\cdot}378$ square inches; and dividing the total disruptive stress by this we have

$$\frac{3{,}900}{29{\cdot}378} = 132{\cdot}71$$

pounds per square inch of metal.

The pressures which these calculations show to be acting upon the metal under the supposed conditions are comparatively insignificant, but they are not unimportant, for they represent the probable minimum of the forces realized in practice, and, serving as indicators of the way such forces operate, they enable us to see clearly and appreciate fully the significance as applied to steel, of the homely old adage, "ye can tell from a little what a good deal means."

Now, after our study of the minimum possibilities arising from "blow-hole" compression and extension, let us see what would be the resultant pressure in case, by any accident of manufacture (I use this expression advisedly; for, whatever form or volume the cavities may assume, and

whatever pressure may ultimately be in them, these items are purely accidental and absolutely impossible of prediction or control), all of the 500 $\frac{1}{4}$-inch "blow-holes" in any cross-section of our 15-inch ingot are reduced by rolling it down to a 1-inch square bar, to $\frac{1}{15}$ of their diameter, still retaining their spherical form. In that event the diameter of the reduced spheres will be ·01666 of an inch, and the volume of each $\frac{1}{3375}$ of a sphere $\frac{1}{4}$ inch in diameter; and, as the pressure of a given weight of gas will be inversely as its volume, it follows that the pressure in these small spheres will be $3,375 \times 120 = 405,000$ pounds per square inch; and as by our supposition there are 500 "blow-holes," each having an area of cross-section of ·00021813 of a square inch, or a total area exposed to pressure of $·00021813 \times 500 = ·109$ of a square inch, and this, multiplied by 405,000 pounds per square inch, gives us 44,145 pounds as the total disruptive stress. To sustain this, we have the solid metal in the cross-section of the 1-inch bar. This we have found to be ·891 of a square inch, which is subjected to a strain of

$$\frac{44,145}{·819} = 49,545$$

pounds per square inch, a strain beyond the elastic limit of most soft steels—a limit of strain which permanently weakens the metal.

The foregoing calculations represent the maximum and minimum possibilities of disruptive pressure which may exist under the supposed conditions; but it is possible that the blow-holes may be larger and more numerous than we have supposed, and that the initial pressure may be more than 120 pounds—all conditions tending to augment the disruptive strain in the final shape given to the steel.

We have frequently heard of instances of the failure of steel plates, which, when subjected to chemical and physical investigation, seem to possess every quality essential for the use to which they had been put. The carbon is found to be in proper quantity; silicon, manganese, phosphorus and sulphur are not present in objectionable proportions; nevertheless, the plate has failed; and hitherto

there has been no satisfactory explanation for this anomalous state of affairs; but if it be admitted that at the point of rupture there may have been a string of blow-holes heavily charged with compressed gases, it is easy to understand that the plate or bar would be much more liable to fail at the point of rupture than where such blow-holes did not exist; at the same time, the metal on either side and in the immediate vicinity of the rupture may be found to have all desirable qualities, and as the rupture destroyed its own cause, no evidence of its existence would appear under any test which could be applied.

I think I have submitted evidence enough to show that the presence of blow-holes in soft steel is a constant source of danger, and that there is no certainty of a sound forging being made from an ingot containing them. It is, therefore, self-evident that the only way to secure sound forgings, bars and plates is to get rid of the blow-holes. Various suggestions have, from time to time, been made for accomplishing this. The chemical means thus far proposed confer properties upon the metal quite as objectionable as the difficulty they were designed to obviate. Some years since, the late Sir Joseph Whitworth proposed and practically carried out a mechanical process of compressing steel in the ingot mould while it was still fluid or plastic, his intention being to destroy the "blow-holes" by the action of the enormous pressure employed. He certainly succeeded in turning out from his works most admirable products in steel; but I have always had a feeling that the high character of his forgings was due more (much more in fact) to the chemical constitution of the metal, and its having been skilfully treated and carefully worked, than to any qualities resulting from its having been compressed while in a fluid state.

Let us examine this matter a little more closely. Suppose *I*, *Fig. 17*, to be a vertical section of an ingot mould filled with fluid steel, *S* (having more or less numerous "blow-holes" distributed through its mass, as indicated by the small circles), which may be forcibly acted upon by the plunger, *P*. Now, as fluids under pressure act equally in all

directions, it is evident that all the "blow-holes" will be reduced in size, and also that the tension of their contained gases will be increased in the inverse proportion to their reduction in volume; but it is not so clear that there is any action that will cause their removal from the steel altogether; in fact, it is not consistent with any known law of physics that a body pressed equally in all directions in a fluid should move at all; the tendency of such pressure would manifestly be to compress the body.

Now let us see what would be the force tending to rupture our supposititious ingot transversely before it has been subjected to compression. The area of the largest cross-section of a spherical blow-hole, $\frac{1}{4}$ inch in diameter, is 0·04908 of a square inch, which, as it is acted upon by a pressure of 120 pounds per square inch, will be subject to a total pressure of $0·04908 \times 120 = 5·88$ pounds; but as there are 500 such holes in any cross-section of the ingot, we have for the total transverse disruptive pressure on such a section $5·88 \times 500 = 2,940$ pounds, which has, of course, to be resisted by the solid metal in the cross-section, which is equal to $15 \times 15 = 225 - (0·04908 \times 500 = 24·5) = 200·5$ square inches, and, on dividing the total pressure by this, we have

$$\frac{2,940}{200·5} = 14·5$$

pounds per square inch on the metal.

Now, let us ascertain what will be the transverse disruptive force if the original "blow-holes" are reduced to one-half their diameter by compressing the molten steel. The area of the largest cross-section of a sphere $\frac{1}{8}$ inch in diameter is 0·01227 of a square inch, which will be acted upon by a pressure of $120 \times 8 = 960$ pounds per square inch, or $0·01227 \times 960 = 11·78$ pounds, which, multiplied by 500, gives 5,890 pounds of total disruptive strain, which is resisted by the solid metal in the cross-section, or 225 square inches $-$ $(0·01227 \times 500 = 6·13$ square inches$) = 218·87$ square inches of solid metal. Dividing the total pressure, 5,890 pounds, by this, we have a pressure of 26·91 pounds per square inch upon the metal. Thus we see that by the com-

pression of the "blow-holes" to one-half their diameter, the strain which the metal is called upon to resist is increased 78 per cent.

It will, doubtless, be urged that the compressed steel is found to be actually stronger than that not so treated. This is true; but there is no evidence to show that this increment of strength is due to the closing up or removal of the blow-holes; on the contrary, we have shown that the metal is called upon to resist a greater strain per square inch after than before the compression, and if there were no other change in the metal save that due to the reduction of the size of the "blow-holes," it must necessarily be less able to resist tensile strain after than before compression. It is probable that the observed increase of strength after compression is entirely due to the forcing of the molecules of the metal into more intimate contact; for it is a well-known fact

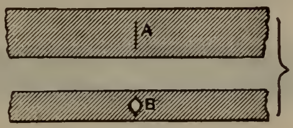

FIG. 13.

that the strength of both iron and steel is augmented by forging, and fluid compression of steel must be regarded as a species of forging.

I now desire to call your attention to a species of cavity —much too frequent in forgings of steel—that does not originate in the manner already described. If a large cold ingot be put into a furnace too highly heated, its exterior surface will expand so much faster than the parts at or near its axis as to strain the metal in the interior of the ingot beyond its elastic limit, and oftentimes actually to rupture its central continuity, as is shown at *A* in *Fig. 13*. Such a breach may, in some cases, have a diameter equal to half that of the ingot.

An ingot thus internally fractured, if hammered or rolled down to a smaller section, will have a cavity developed in the center of its mass, as shown at *B*, and, unless the existence of this cavity is discovered, serious difficulty may

result from the use of such a forging as a part of any mechanism. It is not at all impossible for a number of such cavities to be formed in the same ingot, if the heating be sufficiently rapid, in which case the initial rupture would occur at *A*, *Fig. 14*, at or near the center of the ingot; a second and third fracture would then take place almost simultaneously at *B*, *B*, about half way between *A* and the two ends of the ingot; and, finally, a third set of internal breaks may be formed at the points *C*, *C*, *C*, *C*, thus dividing the ingot into eight nearly equal parts of solid metal. The diameters of the several ruptures would vary in the following order, viz.: That at *A* would be the largest, those at *B*, *B* somewhat less, and those at *C*, *C*, *C*, *C* least of all. Such an ingot—if the internal ruptures were not too large—might be forged into a propeller shaft and actually put into a vessel without the defects being discovered until it was twisted asunder on its first voyage. Such possibilities of careless-

FIG. 14.

ness in the manufacture of heavy forgings of steel as I have described, make it highly desirable that some method be devised to detect the presence of such internal ruptures before much time and labor have been expended upon the forging, and also to prove its soundness when completed. Nearly thirty years ago a plan for this purpose was proposed by Mr. S. M. Saxby, R.N., and some extended experiments to test its practical value were made by direction of the Admiralty. But although the early investigations were very promising, the method has not become established as one of the acknowledged reliable means of testing forgings of iron or steel.*

It is possible that some method of electrical examination may be found of service in testing the soundness of forg-

* This method is described in an article first printed in *The Engineer*, December 7, 1867, reprinted in *Engineering*, December 13, 1867, and subsequently embodied in Kohn's "Treatise on Iron and Steel," 1869.

ings, and I will venture to suggest the following: Let *A*, *Fig. 15*, be an internal rupture in the ingot, *I*, to the extremities of which are connected the wires, *P*, *N*, of the battery, *B*, having in the circuit a galvanometer, *G*. Under these conditions the galvanometer needle will be deflected a certain amount, which is a function of the strength of the current and the resistance of the circuit; and if by any means the resistance of the circuit be diminished, the deflection of the needle of the galvanometer will be increased. For instance, if, in the proposed apparatus, the wire, *N*, be moved toward the left, for each inch of movement there will be a corresponding increase of deflection of the needle; but when the wire passes a point opposite the rupture, *A*, the law of the increase of deflection will suddenly change, and a considerable increase of deflection of the galvanometer will be noted, thus indicating the presence of an internal breach of continuity in the ingot or forging under examination.

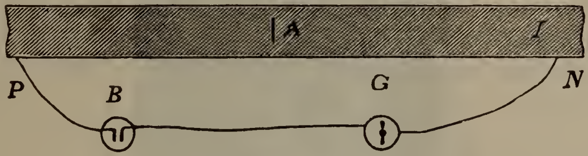

FIG. 15.

Thus far I have spoken only of the transverse internal rupture of steel ingots in consequence of too rapid heating; but longitudinal internal ruptures can be, and too often are, produced by the same cause.

In *Fig. 16*, let *A*, *B*, *C*, *D*, represent a cross-section of a steel ingot. If too rapidly heated, the opposing sides, *A*, *B* and *C*, *D*, will expand so much faster than the center that an internal rupture, *E*, *F*, may be formed; and the expansion of the sides, *A*, *C* and *B*, *D*, may in like manner develop a similar rupture, *G*, *H*, located in a plane at, or nearly at, right angles with that already named.

Such ruptures, though generally situated in planes at, or nearly at, right angles to one another, are not confined to planes so situated; for the planes of rupture may coincide with the diagonal planes of the ingot, or may occupy any

position between such diagonal planes and that shown in the figure. In fact, their position is fixed by the resultant action of two forces, due to the expansion of the exterior of the ingot by the sudden heating, modified by the powerful internal strains existing in the cold ingot, and tending to separate the metal at its center. These strains were established at the time the metal originally solidified in the ingot mould, and are occasioned by the outside of the ingot cooling while its interior was either fluid or plastic; and as the whole mass becomes cold, its interior, by the force of cooling contraction, is strained in many cases beyond its limit of elasticity, which limit may, with propriety, be defined as the beginning of rupture. An ingot of steel thus inter-

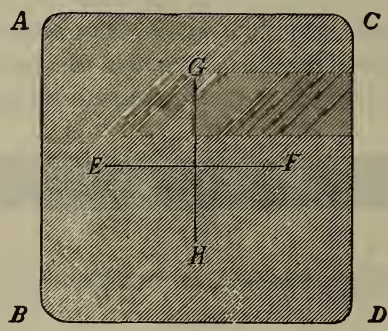

FIG. 16.

nally strained would require merely the small addition to the tension which a too rapid heating of its outside would furnish, to produce such interior longitudinal fractures as have been described. The extent of the influence of such internal strains in all stages of the manufacture of steel is very irregular and uncertain, and this fact makes them all the more worthy of consideration in all cases in which steel is to be subjected to uses which involve the application of sudden and violent shocks.

It is not at all improbable that in many instances ingots are ruptured internally, both transversely and longitudinally, thus aggravating the evil of either single species of rupture. If such an ingot were forged into a heavy crankpin, its whole interior would abound with most irregular

and intricate imperfections, although at the same time the ends and cylindrical surface of the forging might have every appearance of soundness.

As a practical illustration of this, I cannot do better than quote the description of a defective forging given by Prof. Thomas Egleston in the *Transactions* of the American Society of Mechanical Engineers, Vol. VII, p. 263. He says: "I have recently had occasion to examine a forged crank-pin, made with great care from the best of open-hearth steel. It was rough turned to 16⅜ inches. To ascertain its quality in the center, a 1½-inch hole was bored through it. This hole revealed so large a number of cracks and cavities that the hole was increased to 4 inches, in the hope of cutting them out. Defects of considerable size were still found. The pin was then sawn in two (planed apart longitudinally) when single horizontal cracks 10 inches long and ⅜ inch wide were found, and inclined ones 7½ inches in length, in which were cavities ½ inch wide, to say nothing of defects of minor importance.

"None of these defects would have been revealed but for the forethought of examining the center of the piece. If it had been used without this examination, it would have produced great disaster."

I also have had an opportunity of examining the forging described by Professor Egleston, and was told that it was made by one of the oldest and most experienced manufacturers of such work in this country. My experience teaches me that such defective forgings are far more common than the managers of our steel works and forges are disposed to admit or even believe.

It is a common opinion that one of the reasons why steel forgings are often found hollow in their interior is the failure to work them under a sufficiently heavy hammer; but no hammer, not even "the hammer of Thor," can do more than aggravate the evil of internal ruptures in ingots of steel.

In treating of the influence of confined gases under pressure in the blow-holes of steel ingots, I have only thus far considered the case of gases at ordinary temperatures;

but if the ingot were heated to 1,000° F. (a dull red), the pressures would be three times as great as they originally were; that is to say, the original pressure of 120 pounds would become 360 pounds per square inch; and it is self-evident that this increased pressure will not tend to augment the strength or soundness of manufactured steel.

From what has been said, it will justly be inferred that perfect homogeneity is absolutely essential to the trustworthiness of steel. Forgings made from ingots containing

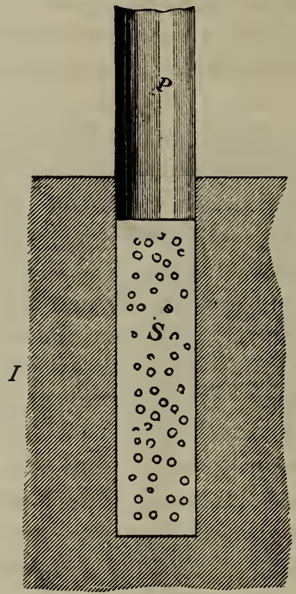

FIG. 17.

blow-holes must always be objects of suspicion. In gun forgings and armor-plate, solidity and soundness of structure are especially necessary.

It seems to the last degree absurd to spend labor and treasure in filling an armor-plate with thousands of magazines of force, every one of which is loaded with compressed gases, ready and anxious to contribute to its destruction. Such a condition is of material assistance to the penetration of shot, and is largely, if not wholly, responsible for the

failure of such plates as are not found satisfactory under fire.

What confidence can be placed in gun forgings made from material honey-combed with imperfections?

Steel containing gas-filled vesicles is especially objectionable in case the use to which it is put requires that it be hardened. On this point the experience of some eminent experts in the employment of steel will be of interest.

Of the effect of internal strains in steel used for the construction of cannon, Col. Eardley Maitland, R.A., Assoc. Inst. C. E., superintendent of the Royal Gun Factory at Woolwich, in a paper published about ten years ago, said: "On a review of the results obtained, the author, having seen so many instances of the fracture of steel, sometimes spontaneous and sometimes under stresses quite inadequate to produce the result, was of the opinion that internal strain was the gun-maker's worst enemy, and that it was a question of great moment whether it was worth while to incur the risk of setting up such strain by oil-hardening." If the distinguished author had said, instead of "setting up," augmenting "such strains," he would more nearly have described what actually occurs in hardening steel.

In the discussion of a paper communicated to the American Society of Mechanical Engineers, by Prof. John E. Sweet,* Mr. Henry R. Towne, President of the Yale & Towne Manufacturing Company, speaks of numerous unsuccessful attempts to harden certain castings of steel, and states that it was finally discovered "that the steel hardened beautifully *inside*, but that there was on the outside a thin skin of metal, about $\frac{3}{100}$ to $\frac{4}{100}$ inch in thickness, which, except by the cyanide process, did not harden at all. In all of the castings there was perfect hardening under this skin; and finally, the moral of this is that we should *look below the surface*"—a moral, I will add, which should not be forgotten by those who hope to succeed in the employment of steel.

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* "The Unexpected Which Often Happens," *Trans. Am. Soc. Mechanical Engineers*, Vol. VII, pp. 156 to 160.

In the same discussion, Mr. Geo. M. Bond, Superintendent Gauge Department, Pratt & Whitney Manufacturing Company, said: "We had occasion to make a set of gauges in which the sizes were all $\frac{2}{100000}$ of an inch larger than the nominal sizes, and, five days after the gauges were finished, one of them suddenly gave way in the center, a crack extending around it spirally, but not so as to injure the ends of the gauge. Out of curiosity, I thought that I would measure the uninjured part to see whether any change had come in the diameter, and I found at both ends the diameter had enlarged 40 divisions of the micrometer, which is equal to $\frac{6}{100000}$ of an inch, and which, as magnified, represented a space to the eye of about $\frac{3}{16}$ inch under the microscope. This shows, I think, that if steel hardens at all, the internal strain must be something tremendous."

Prof. William A. Rogers, at that time Assistant Professor of Astronomy in Harvard University, in the same discussion, said: "The unexpected has *always* happened to me in this matter of obtaining hardened steel which has a homogeneous temper throughout the entire mass. The nearest approach to an even temper which I have ever been able to obtain has been at the works of Miller, Metcalf & Co., of Pittsburgh, and of Brown & Sharpe, of Providence. A short time since, I asked the latter firm to set a price upon a hollow steel cylinder 6 inches in diameter, 3 feet in length, having walls $\frac{1}{2}$ inch in thickness, hardened and ground on the outside only.

"The price which was set, from $300 to $500 without guarantee against flaws, may be taken as the estimate of the extreme uncertainty always attending any difficult case of tempering, held by those who have a full comprehension of the difficulty of the problem. The difficulty of giving a homogeneous temper is so great, according to my experience, that it is never perfectly done. The test which I apply as the gauge of an even temper is a very severe one. If all the lines ruled upon a highly polished bar of tempered steel have the same appearance, the temper of the graduated surface is good. I have, however, never yet seen a set of graduations in which the diamond has, with a constant pres-

sure, cut all the lines to the same depth. The diamond acting upon this polished surface detects the lack of homogeneity in the most perfect manner. If there is any person in this country, or in the world for that matter, who can temper a bar of steel 3 feet in length and for a depth of even $\frac{1}{4}$ inch, at any price, I should be glad to make his acquaintance."

Mr. George Ede, in that chapter of his work on "The Management of Steel" (edition of 1866) descriptive of the method of "toughening of steel in oil," as at that time practised "in the Gun Factories' Department of Her Majesty's Royal Arsenal, Woolwich," says, relative to hardening solid steel shot: "Thick lumps of highly carbonized steel, whether hardened in oil or pure water, or water with a film of oil upon its surface, cannot be hardened without becoming fractured either internally or externally."

In this matter of hardening steel, the value of the "personal equation" of the workman is very important. It is not uncommon to find a practical mechanic who usually has good success in the use of a certain kind of steel with which his neighbors, equally skilful perhaps in other matters, can do nothing. So often have I encountered this fact, that I am inclined to believe that if a person in pursuit of information as to the proper quality of steel to use for any given article should travel through this land and obtain the honest opinions of all who were making the article in question, "the last state of that man would be worse than the first;" for the chances are that every person consulted would have an opinion differing from those of his fellow-craftsmen; and, although when our traveler started on his search for technical wisdom he was positive that he knew nothing, he could not rejoice in even that negative certainty when he returned. In the present state of our knowledge, there is no recognized uniform, scientific method of hardening and tempering steel; all we have is a tentative art, as crude in its development as it is obscure in its origin.

After thus discussing the defects of the ordinary method of manufacturing steel, I may be asked how these defects are to be overcome.

I answer, not by removing them, but by preventing the development of their causes—"blow-holes" and internal ruptures. The first can be prevented by casting the steel in a vacuum; that is to say, by exhausting the interior of the ingot mould and allowing the stream of molten steel to fall into it, without the possibility of its dragging air along with it. The second can only be avoided by careful heating of ingots which contain no gas-filled blow-holes.

Eternal vigilance is the price of excellence!

NOTES AND COMMENTS.*

MOLECULAR ANNEALING.

The Committee on Science and the Arts of the Franklin Institute is now engaged in the investigation of the interesting observation announced by Mr. A. E. Outerbridge, Jr., chemist to the Wm. Sellers Company, that cast iron, under the influence of repeated shocks or blows, gains notably in strength.

The announcement of this fact was made by Mr. Outerbridge, at the recent Pittsburgh meeting of the American Institute of Mining Engineers, as the result of experimental demonstration extending over a period of several years.

The facts, noticed apparently for the first time by Mr. Outerbridge, are directly opposed to the old and universally accepted notion that cast iron crystallizes and weakens under shock or continued vibration, and his announcement has naturally attracted an unusual amount of attention in the technical press.

One of the most intelligent criticisms of Mr. Outerbridge's work appears in the editorial columns of the *Scientific American*, from which we reproduce the following abstract:

Mr. Outerbridge noticed some years ago that "chilled cast-iron car-wheels rarely cracked in ordinary service after having been used for any considerable time; if wheels did not crack when comparatively new, they usually lasted until worn out or condemned for other causes." Although this curious fact was noticed, its real explanation was not discovered at the time, the cracking of new wheels being attributed to imperfect annealing in the oven.

In 1894, he had occasion to test some cast-iron bars for the Sellers Company. Before testing, they were placed in a tumbling barrel to be cleaned, and when they came to be broken in the transverse testing machine he

* From the Secretary's monthly reports.

"noticed with surprise that the average strength of the entire series was considerably higher than was usual with similar iron mixtures." A careful inquiry was made to ascertain the cause of the difference; but it was found that the machine was in good order and that the metal was of normal composition. The next step in the investigation was to cast twelve bars from one pattern and one runner. Six of these were cleaned by the tumbler and six with a wire brush. Upon breaking the twelve bars in the machine, it was found that those which had been subjected to four hours' incessant concussion in the tumbler were 10 to 15 per cent. stronger than the other bars! Various explanations were offered and proved by experiment to be false, until Mr. Outerbridge suggested that the increase of strength might be due to the "mobility of molecules of cast iron at ordinary temperature when subjected to repeated shocks." This theory was tested by subjecting each of six new cast-iron bars to 3,000 taps with a hammer upon one end. When they were broken in the machine they showed the same increase of strength as the bars that had been cleaned in the tumbler. He reasonably concluded that he had proved his case, and the engineering world is certainly indebted to him for the discovery of a most remarkable property of cast iron.

Mr. Outerbridge claims that while it is very well known that the annealing of castings increases their strength by releasing the strains set up in cooling, it is not known that "the molecules of cast iron are capable of movement (for they do not touch each other) without the necessity of heating the castings, and they can thus re-arrange themselves in comfortable relation to their neighbors and relieve the overcrowding near the surface of the casting; or, in more technical words, a molecular annealing may be accomplished at ordinary temperatures, which will release the strains in the castings, precisely as does annealing by slow cooling in heated pits or ovens."

In addition to the transverse tests already enumerated, a series of impact experiments by means of a falling weight was carried out.

"Six of the 1-inch square test bars, cleaned with the wire brush, were broken upon the impact machine by dropping the weight from a sufficient height to break each bar at the first blow; the six companion bars, also cleaned with the brush, were then in turn subjected to blows numbering from ten to fifty each of the same drop weight, falling one-half the former distance, these blows being insufficient to break the bars. The weight was then permitted to fall upon each of these bars in turn, from the height at which the six bars previously tested were broken on first blow. Not one bar broke. Two, three, six, ten, and in one case fifteen blows of the same drop, from the same extreme height, were required to break these bars. In another similar case the weight was dropped once from the former maximum height, then raised by inches until four more blows, each fall being 1 inch higher than the last, were delivered before breaking the piece. Subsequent tests gave still greater gains in strength."

It was pointed out that "molecular annealing" differed from annealing in the oven in that it cannot change the chemical constitution in any way; and it is merely claimed that "every iron casting when first made is under a condition of strain, due to difference in the rate of cooling of the metal near

the surface and that nearer the center, and also to difference of section; that it is possible and practicable to relieve these strains by tapping repeatedly the casting, thus permitting the individual metallic particles to rearrange themselves and assume a new condition of molecular equilibrium."

It is suggested, in conclusion, that all castings which are to be subjected to sudden and severe strains in actual service should never be tested at first up to anything like their full capacity. This applies to such castings as steam-hammer frames, housings for rolls, and possibly to cast steel and all metal castings. The influence of shock upon the various forms of castings other than iron is now being made the subject of experiment.

THE WELSBACH PATENTS IN THE ENGLISH COURTS.

The *Engineering and Mining Journal* gives the following *résumé* of the result of the recent litigation affecting the validity of the Welsbach patents:

After much delay, the actions in the English court by the Incandescent Gas Light Company against the De Mare Company and the Sunlight Incandescent Gas Light Company, for infringement of the Welsbach patents, were heard before Mr. Justice Wills, in the Queen's Bench division during the week ending April 18th. On the last-mentioned date the judge gave his decision in both actions, and briefly, before entering into details, we may say that the practical results are that the De Mare system is pronounced an infringement, while the Sunlight system is not. The patent on which the plaintiffs relied is that granted to Welsbach, and numbered 15,286, of 1885. In this patent the inventor claims the use of a mantle made by impregnating a fabric with the salts of the rare earths, ammoniating and igniting, so as to leave a skeleton of the oxides of the metals of the rare earths, the mantle thus formed having the property of glowing with an intense light when subjected to the heat of a gas flame. In the De Mare system the structure used is not a circular mantle, but is a plume or fringe of loose threads hung from a platinum wire and disposed in a plane, so as to be adapted for use in connection with an ordinary fishtail gas burner. The composition of the solution with which the threads were to be treated is, to all intents and purposes, identical with that used in the Welsbach system, but the threads after impregnation are not ammoniated, but ignited at once. In replying to the action, the De Mare Company put in many pleas attacking the validity of the Welsbach patent, but all of these failed miserably, so that their only point which could be considered worthy of attention was their claim that their plume or fringe was not a fabric such as was referred to in the Welsbach patent. In this case, also, the judge decided against them, as Welsbach specially states in his claim that the exact shape of the mantle shall depend on the nature of the flame to which it is to be applied.

The Sunlight Company relied on their patent, granted to Dellwik, according to which the fabric in the form of a mantle is treated with a solution of aluminum and zirconium salts, and afterward coated with a solution of chromium salt. In this way, after ignition, a mantle is obtained consisting of a structure of alumina and zirconia coated with chromic oxide. No mention

is made in the Dellwik patent of any rare earths, and as the use of such forms an essential point of Welsbach's patents, the Dellwik patent is not an infringement of the Welsbach.

It will be noted from the above judgments that the contention of the Incandescent Gas Light Company that the Welsbach patent covered the use of mantles made by igniting fabrics impregnated with the salts of any mineral substance that glows, quite falls to the ground. It is obvious that if the inventor had made such a claim it would have been invalid, as being an attempt to obtain protection for inventions which were not made at the time. Welsbach wisely confined his patent to such matters as he was sure of, and left it open to any one else to find other salts and oxides which would effect the same purpose. As Mr. Justice Wills remarked, it is the fate of a patentee who desires to obtain a perfectly valid patent to leave some loophole through which those following in his footsteps and emulating his success may creep in and share the rewards of his genius.

SCIENTIFIC BREVITIES.

Apropos to the lately discovered importance of *fluorescent substances*, the following directions for preparing the platino-cyanides will probably be of interest. The method is described by A. Schertel in the *Berichte*. Platinum chloride is precipitated by hydrogen sulphide at 60° to 70° C., and the well-washed platinum sulphide is dissolved in a warm solution of potassium cyanide. On evaporation, the potassium platino-cyanide ($K_2Pt(CN)_4$, $3H_2O$) crystallizes out, and equal parts of potassium sulphide and potassium thiocyanate remain in the mother-liquor. If a solution of barium cyanide be used, the barium platino-cyanide is obtained. With commercial potassium cyanide, containing large quantities of sodium cyanide, Schertel obtained the beautiful double salt ($KNaPt(CN)_4$, $3H_2O$) described by Martius.

Recent experiments have disclosed some important facts in reference to the toxic properties of the products of disintegration of animal tissue, which give rise to the phenomena of fatigue. It has been demonstrated that these are truly the effects of a species of *auto-poisoning*. Maggiori, Mosso, Wedensky, and others, find that, if the blood of a fatigued animal be injected into another animal that is fresh and unfatigued, all the phenomena of fatigue will be produced. Wedensky finds the poison to be similar to the deadly vegetable poison, curare. The poison engendered by fatigue is of the same chemical nature, and is as truly a deadly poison. In case it is created more rapidly than can be carried off by the blood, the organism suffers seriously.

The *Scientific American* has the following in reference to an extremely interesting series of experiments on the action of a powerful magnetic field on the cathodic rays in Crookes' or Hittorf's tubes, described by Herr Kr. Birkeland, in the *Elektroteknisk Tidsskrift*, Christiania. These experiments prove that in such a field the cathode rays are strongly deflected in the direction of the lines of force, and can even be concentrated upon the surface of the tube until the glass melts. Moreover, the evidence suggests that the rays

which emanate from one and the same cathode fall into groups, of which the physical constants are connected by some definite law, just as are the frequencies of the different tones emitted by a vibrating rod. The investigation has an important bearing on the theory of the aurora borealis. The Danish meteorologist, Herr A. Paulsen, is of opinion that the aurora owes its origin to phosphorescence of the air produced by cathodic rays in the upper strata of the atmosphere, and Herr Birkeland suggests that the earth's magnetism may be the cause of this phosphorescence becoming intensified in the neighborhood of the terrestrial poles.

PROPOSED EQUIPMENT OF THE NEW YORK SURFACE ROADS WITH COMPRESSED AIR MOTORS.

The Metropolitan Traction Company, which controls altogether about 132 miles of street railway in this city, and carries daily upward of 650,000 passengers, is contemplating an important change in the motive power of a large portion of its lines. About 32 miles of the system are at present operated as cable and underground trolley lines, and the plant is of the latest pattern and thoroughly up to date; but the greater part—fully 100 miles of the lines—is still worked by the slow and objectionable horse car. Several months ago the company determined to abolish the horse car and introduce in its place some form of mechanical traction, and, in the interval, its agents have been making an exhaustive examination of the many systems of street-car traction, which are being operated in Europe and America.

It has been determined to make a thorough trial of a compressed air motor, which has been designed by Joseph H. Hoadley, of the engineering firm of Hoadley Brothers, who is now associated with the American Wheelock Engine Company, of Worcester, Mass. We are informed by the Metropolitan Company that at a private trial recently had at the Worcester works, before the engineers and officials, the Hoadley motor showed a remarkable efficiency, as compared with any compressed-air motor which they had previously subjected to trial. At present, ten of the company's cars are being equipped with the new motor, and if they prove as successful in service as the experimental car which was recently tested, it is likely that all the existing horse-car roads will be similarly equipped.

The air will be carried in two cylindrical steel tanks, placed between the trucks and beneath the floor of the car, and they will be charged at an initial pressure of 2,000 pounds to the square inch. The power house at 147th Street and Lenox Avenue, will contain a 500 horse-power Greene-Wheelock engine and a Minerva air compressor, the reservoir capacity of the plant being 5,000 cubic feet. The compressed-air motor is being adopted in preference to trolley or cable traction, not merely from motives of economy, but also with a view of securing a service which shall be free from the interruptions to which the cable and trolley systems are liable.

The operation of these cars will be watched with close attention, not merely by the company which is making the experiment, but also by the engineering world at large. Engineers in the United States have been so fully

occupied with the development of electric traction—and it has had a growth and a success which is phenomenal—that comparatively little attention has been paid to other methods of traction which utilize the oil, gas, and compressed-air motor. As compared with the cost of the electric and cable systems, the compressed-air and gas motors, which are being increasingly used in European cities, are said to be showing remarkably economical results. Chief Engineer Pearson, of the Metropolitan Company, is now in Europe for the purpose of personally inspecting the working of some of the more important plants that are operated on the above systems.—*Scientific American.*

CONVERSION OF A TREE INTO A NEWSPAPER IN ONE HUNDRED AND FORTY-FIVE MINUTES.

The *Scientific American* quotes from the *Centralblatt für Oesterreich-ungarische Papier-industrie* the following account of a curious experiment:

A very interesting experiment was made on April 17th last at Messrs. Menzel & Co.'s paper and wood-pulp manufactory, at Elsenthal, in order to ascertain what was the shortest space of time in which it was possible to convert the wood of a standing tree into paper, and the latter into a journal ready for delivery. This experiment is of importance, because it shows what rapidity can be attained by the concurrence of practical machines and favorable conditions.

Three trees were felled in a forest near the establishment at thirty-five minutes past seven, in the presence of two of the owners of the manufactory and a notary, whom they had called upon to certify as to the authenticity of the experiment. These trees were carried to the manufactory, where they were cut into pieces 12 inches in length, which were then decorticated and split. The wood thus prepared was afterward raised by an elevator to the five defibrators of the works. The wood-pulp produced by these machines was then put into a vat, where it was mixed with the necessary materials. This process finished, the liquid pulp was sent to the paper machine. At thirty-four minutes past nine in the morning, the first sheet of paper was finished. The entire manufacture had thus consumed but one hour and fifty-nine minutes.

The owners of the manufactory, accompanied by the notary, then took a few of the sheets to a printing office situated at a distance of about 2½ miles from the works. At 10 o'clock, a copy of the printed journal was in the hands of the party; so that it had taken two hours and twenty-five minutes to convert the wood of a standing tree into a journal ready for delivery.

PAINTS FOR METALS.

Progressive Age prints the following abstract of some interesting researches on the value of paints for iron-work, made by Professor J. Spennrath, and recently published in the *Deutsche Bauzeitung*. As one result of these, Professor Spennrath concludes that none of the metallic oxides

commonly used combines chemically with linseed oil. The drying process depends exclusively on an absorption of oxygen by the oil, which is facilitated in a purely mechanical way by the presence of the pigment. The value of the different pigments used varies. Thus, zinc-white, when used for outside work, rapidly swells to double its previous volume, owing to the absorption of carbonic acid gas and water. Sulphuretted-hydrogen will cause red- or white-lead to act in a similar way; but, when pure, Professor Spennrath considers these latter two pigments satisfactory. Carbon paints are very stable, as is heavy-spar, but the covering power of the latter is small. In order to test the relative durability of various paints, sheets of zinc were coated with a number of different kinds. The zinc was then dissolved away by acid, leaving a film of paint. All these films, it was found, could be destroyed by the action of dilute nitric or hydrochloric acids, while the vapors of sulphuric and acetic acids acted similarly. Alkaline fluids and gases also destroyed the paints rapidly. Pure water was found to be more injurious than salt water, hence the destructive action of sea-water is to be attributed mainly to the mechanical effects of wash. Hot water was found to act more rapidly than cold. The most important discovery made was, however, the great influence of temperature. Films similar to those already described completely lost their elasticity, and became brittle when exposed to a temperature of 203° F. There was at the same time a large contraction. Similar effects are produced by prolonged exposure to considerably lower temperatures. Blistering he finds to be due to the inner coat of paint being so thick that it has not hardened thoroughly before the second coat is applied.

TECHNICAL NOTES.

M. Moisson is reported to have discovered *a substance harder than the diamond*, in the form of a compound of carbon and boron, produced by heating boracic acid and carbon in an electric furnace, at a temperature of 5,000°. This compound is black and not unlike graphite in appearance, and it appears likely to supersede diamonds for boring rocks, cutting glass, and other industrial purposes. It will even cut diamonds without difficulty, and it can be produced in pieces of any required size.

The question as to the *fusibility of platinum* in a carbon-heated furnace seems at last to have been definitely settled by Victor Meyer, says *Science*. A sheet of platinum, completely inclosed in a mass of fire-clay, was fused to a globule in a blast furnace heated with gas carbon. In this case, action of carbon or of furnace gases on the platinum was absolutely excluded. Under similar conditions, an alloy of platinum with 25 per cent. iridium was unchanged.

A curious phenomenon, first discovered by M. Charles Margot, was shown in a modified form by Professor Roberts-Austen at the recent meeting of the Society of Arts. An electric current was sent through an aluminum wire, raising it to a temperature of 400° above its melting point. Strange to say, it

did not fall, the film of the oxide on its surface holding it intact. In this condition it was attracted, owing to the current within it, by a magnet, and by careful manipulation could be made to tie itself into a knot.

Experiments recently made by the Royal Society of Belgium, in connection with the *welding of metallic bodies by simple pressure* at heats below their fusing points, have demonstrated the fact that the most perfect joints are obtained with gold, lead and tin, and the weakest with bismuth and antimony. In the course of the experiments, cylinders of pure metal, with smooth surfaces, were brought together by a hand-screw, and kept at a temperature of between 200° and 400° for from three to twelve hours. When separated, the break in no case corresponded with the jointed surfaces.

Soldering Glass by means of a metal solder has become a possibility through a recent discovery of an alloy, composed of 95 parts of tin and 5 of zinc, which melts at a low temperature and will firmly adhere to glass. Another alloy of tin and aluminum, containing 10 parts of the latter, melts at 390°, and can be used also for soldering glass. Either of these alloys can be cast upon glass without danger of breaking the glass if it has been previously heated slowly. Castings of these alloys made on glass become firmly adherent, as much so as though they were made on metal.

Nickel Plating of Wood.—Several methods are recommended for the first coating of metal; one of these, the Langbein dry process, consists in quickly pouring over the object a collodion solution of potassium iodide diluted with an equal volume of ether-alcohol, and when just about to set, the object is placed in a weak solution of silver nitrate in the dark; when a yellow color appears, the article is rinsed, exposed to sunlight and covered with copper. Wooden articles for surgical instruments may be treated by immersion in an ethereal solution of paraffin or wax, after which it is dusted with graphite or bronze powder.

Cryostase is a compound having the curious property of solidifying under the influence of heat and again becoming liquid at temperatures below the freezing point. It is the only substance which possesses the property of liquefying when cold and becoming solidified when hot; for although some substances, like albumen, harden at a moderately high temperature, they cannot be brought back to a liquid state even under the influence of a very low temperature. Full details of the composition are lacking. It is said to be made by mixing equal parts of phenol, camphor, and saponine, to which is added a slightly smaller quantity of turpentine.

Carbon Monosulphide.—Dr. Deninger, of Dresden, says the *Practical Engineer*, is reported to have prepared carbon monosulphide pure for the first time, and finds that, instead of being, as described in the text-books, an amorphous red solid, it is really a colorless gas. He prepared it by heating dry sodium sulphide with chloroform, or preferably iodoform, in sealed tubes, to 180° C., the gaseous products being made to bubble through aqueous caustic potash, which absorbed the sulphuretted-hydrogen, and the carbon

monosulphide passed through unabsorbed. By acting upon carbon disulphide with sodium, in the presence of some aniline, the new gas was also obtained. It is colorless, and easily condensable to a clear liquid, which evaporates rapidly and is extremely explosive.

The officials of the Mint Bureau express the opinion that the world's *gold production* for 1896 will equal the aggregate production of gold and silver prior to 1873. The *Iron Age* has the following to say on the subject:

The gold production of the world has been steadily climbing upward since 1890, when it stood at $118,849,700. The figures of 1892 were $146,815,100, of 1893 $57,287,600, and of 1894 $180,626,100. The figures for 1895 have not been fully verified by Director Preston, but a production of $203,000,000 is considered a conservative estimate. The production of 1896 is, of course, still a matter of conjecture, but the increases reported from nearly every country over 1895 are regarded as a safe basis for putting the production of the year at not less than $220,000,000. The United States is expected to show an increase this year from $47,000,000 in 1895 to $50,000,000. This is regarded as the lowest probable production, and $54,000,000 is considered a not improbable figure. This will keep the United States at the head of the gold-producing countries.

PUBLICATIONS RECEIVED.

[In sending books for notice in the *Journal*, publishers are requested, for the information of the reader, as well as for their own advantage, to give the price. This announcement by title will be followed, in most cases, by a review, which will appear at the earliest opportunity.]

Borchers, W. Elektro-metallurgie. Part I. Braunschweig: Harold Bruhn. 1895. 8vo.

Manual of Guard Duty, United States Army. New York: *Army and Navy Journal.* 1893. 32mo.

Oesterreichische Ingenieur-und Architekten Verein. Bericht über Typen für Walzeisen Vienna, Society. 1892. 4to.

Omaha, Neb. Annual Report of the City Engineer for 1894.

Pennsylvania Coal Waste Commission Report. Philadelphia. 1893. 8vo.

Rhode Island State Board of Health. Appendix to the Seventeenth Annual Report. Report of the results obtained with Experimental Filters at the Pettaconset Pumping Station of the Providence Water Works. Providence: State Printers. 1896. 8vo.

Tuttle, Herbert B. Chemistry at a Glance. A Study in Molecular Architecture. No. 1. Oxides. New York. 1896. 8vo. Price, 60 cents.

U. S. Geological Survey. Production of Coal in 1892. By E. W. Parker. Extract from "Mineral Resources of the United States." Washington: Government Printing Office. 1893. 8vo.

University of Illinois: Catalogue, 1895–96. Urbana: University. 12mo.

Wheeler, Olin D. Sketches of Wonderland. St. Paul: Northern Pacific Railroad Company. 1895. 8vo. Price, 6 cents.

Report of the Tests of Metals and other materials for Industrial Purposes, made with the U. S. Testing Machine at the Watertown Arsenal, Mass., etc. Washington: Government Printing Office. 1895. I. W. Rielly, Major, Ordnance Department, U. S. A., Commanding.

BOOK NOTICES.

Compressed Air. Practical information upon air compression and the transmission and application of compressed air. By Frank Richards, Mem. A. S. M. E. New York: John Wiley & Sons. 1895.

The matter contained in this compact volume, of some 200 pages 12mo, has been revised and arranged in book-form from the author's contributions to the subject, which have appeared during the past two years in the pages of the *American Machinist*, where they attracted much favorable comment. The author is among those who believe that the capabilities of compressed air for power transmission and other useful applications have by no means been duly appreciated. His book gives much useful information on the subject and dispels many current errors. W.

Encyclopédie scientifique des Aides-Mémoire. Librarie Gauthier-Villars et Fils, Quai des Grands-Augustins, 55, a Paris. Price, francs 2.50 to 3 francs per volume.

Since our last notice of this publication, the following volumes have appeared. These are all published in uniform style, and each constitutes a volume complete in itself, encyclopædic in treatment, upon the subject to which it relates. No publication with which we are acquainted quite fills the place of this one, or so adequately meets the needs of one requiring a small yet comprehensive library covering all branches of applied science.

Hennebert, Lieutenant-Colonel du Génie, ancien Professeur à l'École militaire de Saint Cyr, aux Écoles des Mines et des Ponts et Chaussées et à l'École supérieure de guerre. *Attaque des Places.*

Lefèvre, Julien, Professeur à l'École des Sciences et à l'École de Médecine de Nantes. *La Spectrométrie. Appareils et mesures.*

Boursault, Henri, Chimiste à la Compagnie des Chemins de fer du Nord. *Calcul du temps de pose en Photographie.*

Gouilly, Al., Répétiteur à l'École Centrale. *Géométrie descriptive.* 3 vols

Lefèvre, Julien, Professeur à l'École des Sciences et à l'Ecole de Médecine de Nantes. *La Spectroscopie.*

Seguela, R., ancien Elève de l'École Polytechnique. *Les Tramways; voie matérielle.*

Moissan, H., et Ouvrard, L. *Le Nickel.*

Roads and Pavements in France. By Alfred Perkins Rockwell, A.M., Ph.B., formerly Professor of Mining at the Sheffield Scientific School and at the Massachusetts Institute of Technology. First edition. New York: John Wiley & Sons. 1896. Pp. 107, 12mo. Cloth, $1.25.

This manual of road-making gives, in concise form, the methods and practice in vogue in France for the construction, maintenance and repairs of highways in city and country, much of which could be followed with advantage in this country. The book is confined strictly to the practical details of the subject, and the illustrations (drawn approximately to scale) add notably to the usefulness of the text. The author acknowledges his indebtedness to several official publications of the French Government for the data presented.

The question of road improvement in this country is, happily, coming into greater prominence every year, and has already become a live question in every progressive community—in striking contrast with the public apathy of only a few years ago. Every contribution to the subject that gives useful information, therefore, should be welcomed. W.

Water Supply (considered principally from a sanitary standpoint). By William P. Mason, Professor of Chemistry, Rensselaer Polytechnic Institute. Mem. Am. Philo. Soc., Am. Chem. Soc., Am. Water Works Assoc., New England Water Works Assoc., Franklin Institute, etc. New York: John Wiley & Sons. 1896. Price, $5.

Professor Mason has laid the engineering fraternity and the water analyst under substantial obligations by his comprehensive and accurate *résumé* of the subject of water supply from the sanitary standpoint. In fact, the treatment of the subject is such as to satisfy the needs of all intelligent inquirers, professional and non-professional, to whom the question of a pure water supply has special interest.

The researches of the chemists and bacteriologists within the past decade or two have thrown a flood of light upon the causes and effects of water pollution, and have practically revolutionized the previously current ideas respecting preventive and curative methods. They have established, beyond the shadow of doubt, the direct and intimate connection between polluted water supplies and the prevalence of certain diseases (such as typhoid fever and cholera), and have demonstrated the fact that the spread of such diseases can effectually be checked by the adoption of certain simple preventive measures. They have demonstrated the vitally important proposition that it lies within the power of every municipality to secure, without excessive cost, a wholesome water supply.

All these matters are set forth with admirable clearness in the work under consideration. The author has taken pains to give references throughout his book to the sources of information, so that the reader desirous of making a more extended study of the subject will find his labor greatly lightened thereby. Professor Mason's work is a timely contribution to the most important sanitary problem of the day. W.

Cours de Physique de l'École Polytechnique. Par M. J. Jamin. Premier supplement, par M. Bouty. Paris: Gauthier-Villars et Fils. 1896. Prix, fcs. 3.50.

The volume above entitled is intended to supplement the "Cours de Physique" prepared by M. Jamin for the students of the École Polytechnique. It covers the subjects of heat, acoustics and optics, and incorporates the latest theoretical considerations in these important branches of physical science.

W.

The Forest Tree Planter's Manual. (Sixth edition.) By J. O. Barrett, Secretary of the State Forestry Association, Minneapolis, Minn. Minneapolis: Progressive Age Publishing Company. 1894.

This is an admirable, practical handbook of information relating to tree culture, issued by the State Forestry Association of Minnesota for free distribution. It could be imitated with advantage by similar associations in other States where the subjects of the preservation of the forest areas, and their artificial extension, have grown to be important questions. W.

A Dictionary of Chemical Solubilities. Inorganic. By Arthur Messinger Comey, Ph.D., formerly Professor of Chemistry, Tufts College. London and New York: Macmillan & Co. 1896. Price, $5.

Chemists have long felt the need of some reliable source of information on the subject of the solubilities, since almost the only accessible work of reference on the subject—that of Storer, which brings down the data to the year 1860—is practically antiquated, although still a classic contribution to scientific literature.

The present work seems to be all that could be desired by chemists, in respect of arrangement, comprehensiveness and accuracy. It will doubtless receive a warm welcome from the profession. W.

The Chronicle Fire Tables for 1896. A record of the fire losses in the United States, by States and Territories, during 1895, etc. New York: The Chronicle Company, Limited. 1896. Price, $5.

This statistical publication fully maintains, in the comprehensiveness and completeness of its fire data, the high standard of former years, and the position of the leading source of reliable information on these topics which we have cheerfully accorded it. In general arrangement the work follows the same plan as previous volumes.

The total fire losses for 1895 are given as $142,000,000, an increase of $2,000,000 over the figures of 1894. It is interesting to note that the *average* property losses, and also the *average* insurance losses, exhibit a decrease. This is a most encouraging factor in the situation, demonstrating increased care on the part of insurance companies, improvement in building construction and in the means and appliances for combatting fires.

These tables are simply indispensable to all who are interested in the subject of fire insurance. W.

Handbuch der chemischen Technologie. In Verbindung mit mehreren Gelehrten und Technickern bearbeitet von Dr. P. A. Bolley u. Dr. K. Birnbaum. Nach dem Tode des Herausgebers fortgesetzt von Dr. C. Engler. Die chemische Technologie der Brennstoffe. Von Prof. Dr. Ferdinand Fischer. Braunschweig: Vieveg u. Sohn. 1896. Preis, 5 mk.

The part above entitled of this standard publication relates specifically to the chemical technology of fuels. The subject is introduced by a general consideration of the thermo-chemistry of fuels, from which their thermal value must be calculated.

Following this, come chapters on the chemical and physical properties of wood, peat and mineral coal, with important historical and statistical data and elaborate tables, giving the constituents and fuel value of many of the European and American coals.

The part concludes with chapters on the formation of coal and the spontaneous combustion of coal.

The chemical engineer, familiar with the literature of his subject, will need no introduction to this thorough and comprehensive handbook, which ranks second in value to none in its special field. W.

A List of and Brief Guide to the Publications of the Pennsylvania Geological Survey. 1874–1895. Compiled by William A. Ingham, Secretary of the Board of Commissioners. Harrisburg: State Print. 1896.

The foregoing pamphlet embraces an alphabetical list of the numerous publications of the Second Geological Survey of Pennsylvania, supplemented by a topical index giving reference to specific subjects of local interest throughout the State. With the assistance of an index of this character, the labor of searching for information through the voluminous literature issued by the Survey is made comparatively easy, and the usefulness of these publications is substantially increased. W.

Weather and Disease. A curve history of their variations in recent years. By Alex. B. MacDowell, M.A., F.R.M.S. London: The Graphotore Co. 1895. Price, 2s. 6d.

The author, in this work, has given an array of statistical data bearing upon the presumable relationship of weather and disease, which, at the least, are strongly suggestive of an intimate connection as of cause and effect. His employment of the graphical method for the exposition and comparison of the data collected greatly simplifies their study, and he has certainly succeeded in exhibiting some new and instructive relationships heretofore unknown and unsuspected.

The field covered by the author is one in which much hypothesis and speculation have been indulged in, and he appears to have been the first to bring to bear upon it the careful method of analysis and comparison. In so far, therefore, his work is a valuable contribution to meteorological science. W.

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LANSTON'S MONOTYPE MACHINE.

[*Being the report of the Institute, through its Committee on Science and the Arts, on the invention of Tolbert Lanston.*]

[No. 1849.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 1, 1896.

The Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the Lanston monotype machine, reports as follows:

In designing this machine the inventor had the object in view to produce individual types, set in lines of equal length, ready to be formed into columns and locked into chases, for use as a printing surface. Instead of setting previously prepared type, as in the old type-setting machines, he selected a process of casting types in the order of their use, and of setting this type into justified lines, and the lines into a column, to be subsequently separated into pages by hand.

The greatest difficulty encountered in all type-setting machines is the problem of the justification of the lines. This problem has been solved, in this machine, by making the word-space types of a variable thickness, after first determining, by an ingenious plan, the thickness of the word-spaces requisite to make each line of the proper length. This determination must, of course, precede the casting of the line, and this was presumably the initial reason for dividing the process of type-setting into two operations, each of which is performed on a distinct machine.

The first of these machines is in some respects similar to a typewriter, but instead of printing common letters, it is constructed to perforate a ribbon of paper, the locations of the perforations determining, Jacquard-card fashion, the characters which the operator puts into it. For each character two holes are punched through the ribbon, which has previously been provided with two rows of marginal holes that act as racks, by means of which the ribbon is advanced with the necessary regularity.

The key-board is of a rectangular form, the keys being arranged in series of horizontal and vertical lines, and the characters placed on these keys in the following order: The characters are divided into as many groups as there are vertical lines on the key-board; those requiring the least space being placed into the first group, the next larger ones into the second group, and so on. To the first group is assigned a space of five units, to the second one of six units, and so forth. By the depression of each key, two holes are punched into the paper ribbon, in line with the marginal holes forming the rack. These punched holes record the location of the character on the key-board, one hole recording the number of the vertical, and the other that of the horizontal row of keys containing the letter struck. At the same time a mechanism is set into motion by the depression of each key for the object of measuring and indicating the space occupied by the accumulating letters. This mechanism is advanced by the depression of each key, by a number of units corresponding to the number of units of space occupied by the type, and this advance is indicated by an

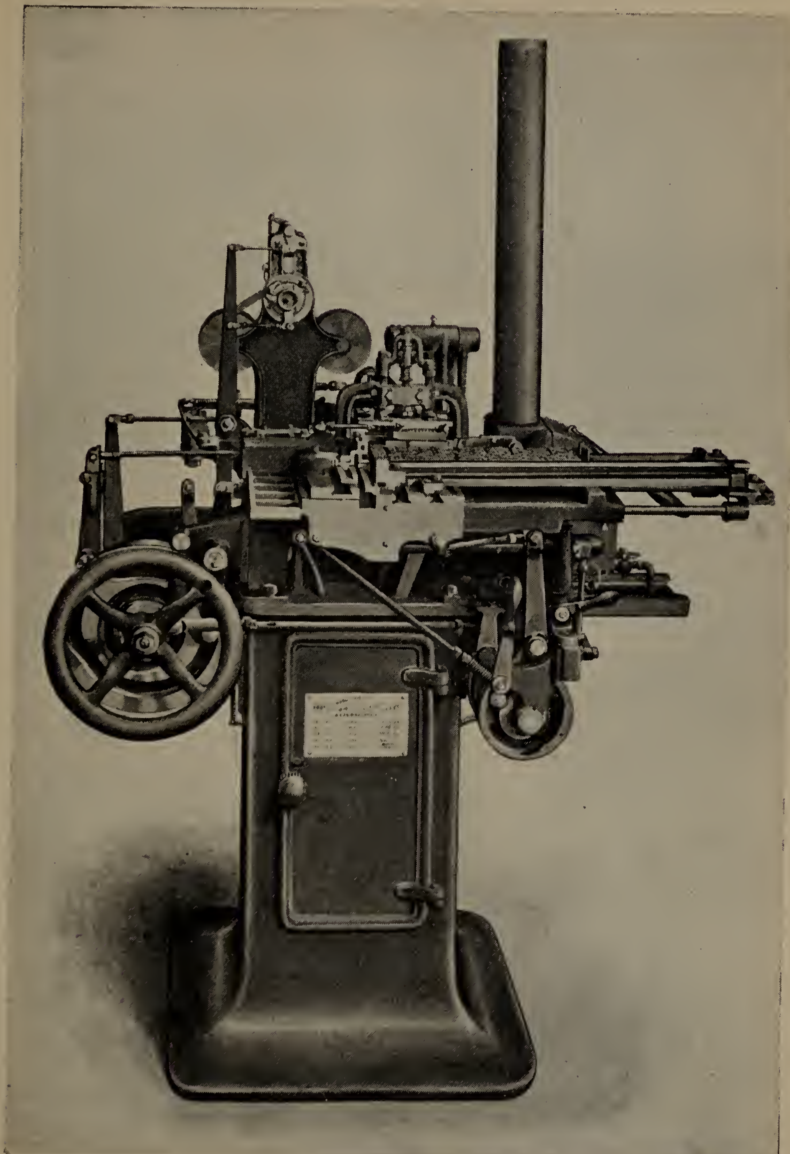

Plate I.—Front View Monotype Casting Machine.
Size : 36 x 42 inches, including galley.

index hand. For each word-space the minimum number of units admissible for this spacing is registered on this mechanism. When the index shows to the operator that the accumulating types would fill a line so far that no additional syllable can be added, it also shows precisely how much space is required to fill the line. This space is distributed among the word-spaces, the number of which is indicated on a dial, by finding the addendum required for each space to fill the deficiency. The requisite division is accomplished, mechanically, by means of a table attached to the index, and the resulting quotient is recorded at the end of each line on the paper ribbon.

While a copy is thus punched, the ribbon is wound upon a spool, and, when placed into the type-making machine, it will enter that machine with the end of copy foremost, passing through it in a reverse direction.

The matrices of the type-making machine are located on a rectangular plate, in two sets of rows, intersecting each other at right angles, in precisely the same order in which the characters are placed on the key-board of the first machine. At every stroke of the machine this plate is caused to make a reciprocating motion in both directions, and each of these motions is so regulated that, on the return stroke, the movement is so limited that the desired matrix will be placed centrally over the mould in which the type is to be cast. To accomplish this a number of stops is provided in the path of each of the two movements, which are operated by compressed air admitted to the corresponding pistons through channels which are closed by the paper ribbon, except where this ribbon is perforated. The location of the perforations determines which of the stops is to be brought into operation, and thus commands the position in which the plate of matrices is retained immediately before the type is cast. By means of a wedge the movement of the plate regulates the variable width of the type-mould to correspond with the width required for the character.

The paper ribbon entering the type-making machine in a reverse direction, the record of the justifying addendum will precede each line. By a pneumatic device this record

is caused to adjust a wedge, which regulates the width of the mould for each word-space occurring on this line. By this means the proper length of the line is assured.

After the matrix-plate has been arrested in that position, which will place the required character directly over the type-mould, the matrix is more correctly centered than the pneumatic stops are able to do, by means of a taper plug entering into one of the conical centering-holes which are located on the reverse side of the matrix-plate, one opposite each matrix, and the molten type metal is injected into the mould. After congealing, the jet is cut off, the mould is opened, and the finished type is transferred, by an ingenious mechanism, to the galley, where it collects in the form of a column, and whence it is taken by hand to be made up into forms.

The investigating committee witnessed the operation of a machine at the printing office of *The Philadelphia Inquirer*, and found it to work exceedingly well.

The rapidity of the ribbon-punching machine depends on the skill of the operator; but since the number of punching machines need not correspond with that of the type-casting machines, the rapidity with which the former machine is used has no direct bearing on that of the machine proper. An expert operator can easily furnish ribbon in excess of the capacity of the type-casting machine. It is, indeed, contemplated to have the writers use the punching machine to enable them to turn in copy on paper ribbons, ready for the type-casting machine. The separation of the processes of making the ribbon copy and casting the type has obviously marked advantages.

The latter machine runs at a speed of about 110 strokes per minute. With the exception of a few strokes at the beginning of each line, each stroke produces a type. The capacity of the machine is stated to be between 4,000 and 4,500 ems per hour, and this capacity is self-evidently independent of the skill of the operator, whose function is that of producing the perforated ribbon.

Matter set up by this machine has the important advantage of admitting of subsequent corrections and alterations, being fully equivalent in this respect to matter set by hand.

PLATE II.—THE LANSTON MONOTYPE KEYBOARD.

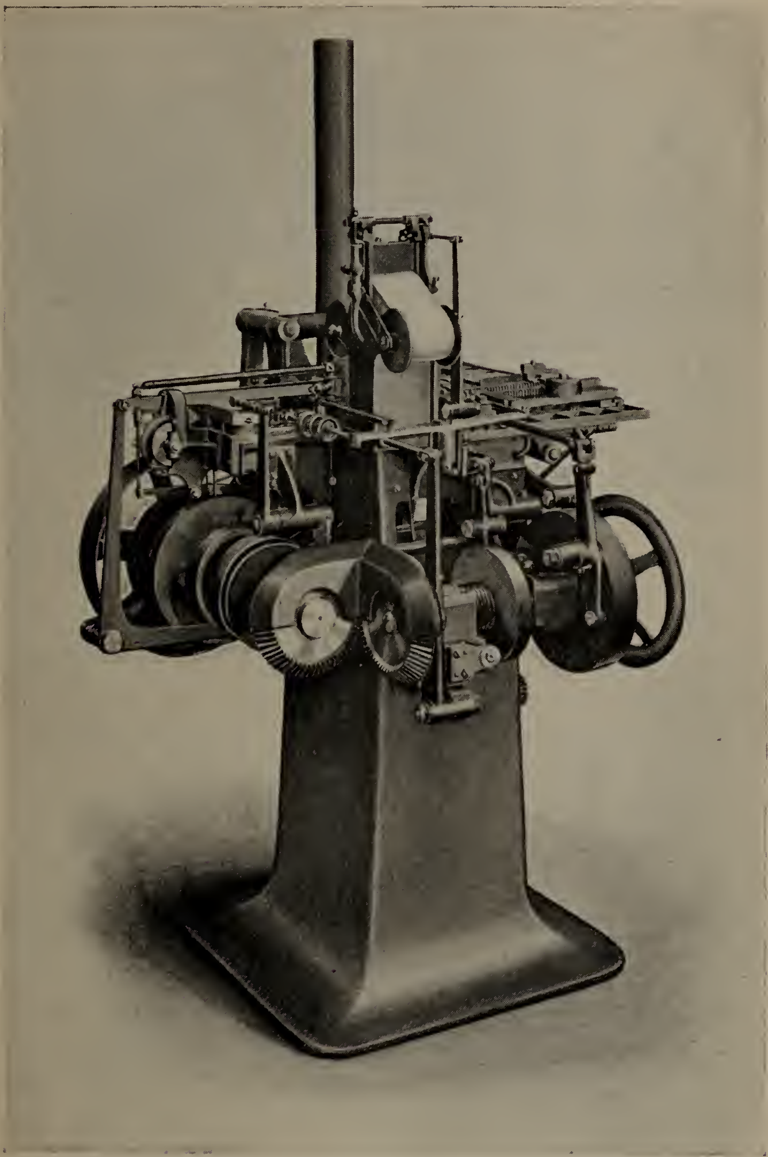

PLATE III.—REAR AND SIDE VIEW MONOTYPE CASTING MACHINE.

This machine casts a perfect type in the ordinary sense of the word, which can be used in the finest magazine and book-work.

After the matter set by this machine has been used, it may be re-melted, or the type may be distributed and used in the ordinary way for hand-work. The waste product of this machine can thus be advantageously utilized.

The investigating committee considers this invention as one of the highest order and importance.

The Franklin Institute, therefore, awards the Elliott Cresson Medal to Tolbert Lanston, of Washington, D. C., for his monotype machine.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, April 8, 1896.

JOS. M. WILSON, *President.*
WM. H. WAHL, *Secretary.*

G. MORGAN ELDRIDGE,
Chairman, Committee on Science and the Arts.

THE RELATIONS OF ELECTRICITY TO STEAM AND WATER-POWER.*

BY CHARLES E. EMERY, PH.D., of New York.

It is a common inquiry of late, by those who wish, in a general way, to keep in step with modern progress—will electric power be cheaper than steam-power? No general answer is possible. The cost depends upon the conditions obtaining at a particular place, and a discussion of the subject can only point out the nature of the conditions and illustrate their application by comparatively few examples.

Steady power is dependent upon some means of storing energy. For the steam engine the best storage is the coal itself. One ton of coal utilized through the organism of a steam engine is capable of practically exerting 1,120 horse-power for one hour. One ton of water, even if it have a fall of 100 feet, would exert no more power during such fall

* A lecture delivered before the Franklin Institute, March 27, 1896.

than the ton of coal falling through the same distance, or about one-tenth of a horse-power for one hour. Storage of water for power purposes is, therefore, only practicable in enormous natural reservoirs.

As yet, electricity is not a source of power, but a means of transmission which enables power to be generated where sources are available, and work to be performed where there is work to be done, and long transmissions are in general commercially desirable wherever transmitted power can be furnished at less cost than an equal power can be developed on the premises.

The facility of developing power in desired quantities where it is wanted has given steam-power a great advantage for many locations; but the great improvements in electrical transmission of recent years will do much to offset this advantage. It is now possible to utilize water-power in mountain fastnesses and at considerable distances from centers of trade and mechanical operations, and transmit it where the energy can be utilized. The industry has long since passed from the experimental stage, and the application to a particular case is a commercial question to be based on an estimate as to the cost of the installation in relation to the work to be done, rather than the practicability of accomplishing the purpose electrically.

The advance has taken place rapidly, but has, nevertheless, been thorough, so that there is no probability that there will be any material change in conditions in the future, and new applications will, in the main, be practically duplications of those already established. This arises from the fact that both of the general features of progress stated have about reached the limit. Electric machinery is now constructed on a business basis and sold for about the same price per pound of finished material as other machinery, the manufacturer depending upon larger sales for profit instead of higher prices, and patents have very much less influence on the result than in former times. The later apparatus has, moreover, as nearly reached the theoretical limit of efficiency as can be desired.

The principal improvements which have made electrical

transmission practical have been in the development of methods and apparatus which will permit the use of higher electrical pressures or electro-motive forces, than formerly. Formulæ based on Ohm's law show that a given amount of energy will be transmitted over conductors of a given size to distances proportioned to the squares of the electro-motive forces. That is, by doubling the E. M. F. the distance may be increased four times. For long-distance transmission the copper in the line is one of the most important elements in the cost, and the above considerations show that, to secure economy in copper, the voltage must be as high as practicable.

The electric pressure is limited by questions of safety and the use of particular apparatus; varying from about 50 to 127 volts for incandescent lamps, which is doubled, so far as transmission is concerned, by the use of the Edison three-wire system, in which part of the lamps are supplied at, say, plus 125 volts, and part at minus 125 volts, while the pressure between the outer wires, or about 250 volts, is used for larger electric motors. Electric railroads are usually operated at from 500 to 600 volts, which is about the limiting pressure which can be endured by human beings, though sufficient to kill a horse. Arc lamps are, however, operated in series, with a difference of potential at terminals of dynamo of 2,000 to 4,000 volts, so that such circuits are extremely dangerous.

It is assumed that it will not be necessary here to elaborately develop elementary details. Most of those present already know the difference between direct and alternating current, and realize the difficulty of generating direct current with high voltages. We will, however, call attention to the fact that alternating current is most advantageous for the electric transmission of power; first, from the fact that the current can be generated and utilized without the use of commutators and brushes, and, second, that alternating currents of a given pressure may be transformed into currents of other pressures, by the use of what are termed "transformers," without the use of moving parts of any kind.

Calling the circuit carrying the original current the "primary," and the parallel circuit the "secondary," the voltage in the secondary may be made any proportion of that in the primary by simply varying the number of turns in the coils, but the work done in each will be the same, less ordinary losses. For instance, 10 ampères at 100 volts in the primary will, in a secondary containing one-tenth the number of turns, give 100 ampères at 10 volts. This is called "step-down" transformation, because the pressure is reduced. If, however, the primary contains a fewer number of turns than the secondary, the pressure in the latter is increased, and it is called "step-up" transformation.

It should be noted that alternating current can be generated at a comparatively low voltage, or one which is safe to human life, and causes no difficulty with the insulation of the moving parts, and that the energy thus developed may, by step-up transformation, be transmitted with lower current and higher voltage to a distance where, by means of step-down transformers, a large current and low voltage may be obtained for lighting and power purposes.

Alternating current motors are of several kinds, such as "synchronous motors," very much like, and running in "step" with, the generators—that is, so as to pass the same number of poles in the same time,—which motors are preferred for large installations. With moderate powers, electric transmission is preferably made with what are called "polyphase currents," or several currents, in which the phases, or maximum E.M.F.'s, are not coincident. In "polyphase motors" of the "induction type" the armatures carry conductors short-circuited on themselves. The action of the alternating current in the coils of the magnets is to cause alternating magnetism to flow across the armature, thus inducing current in the conductors of the armature on the transformer principle, which currents are attracted by the field produced, and motion results.

The eddy currents, produced in a mass of metal subject to alternating magnetism, were early investigated by Prof. Elihu Thomson; but the first conception and practical carrying out of the idea that these currents—if localized by conductors inserted in the iron core of an armature—would be attracted

by the magnets generating them is, doubtless, due to Tesla, whose inventions on this subject are owned by the Westinghouse Company, and form one of the elements of value considered in the recent agreement between the General Electric and Westinghouse Companies in relation to the joint use of patents.

It is also possible to pass alternating currents in at certain points of the armature of an electric generator, and take direct current from the same armature, by means of a commutator and brushes, in the same way as from an ordinary direct-current machine. Such an apparatus is called a "rotary converter."

The application of these various devices for long-distance transmission would be, substantially, as follows: If the power were derived originally from a waterfall, the water-wheel would preferably be directly connected to an electric generator, forming what the speaker has called a "turbine dynamo," to correspond with the term "engine dynamo," so frequently used to designate apparatus consisting of a steam engine operating directly an electric generator. There should be a sufficient number of these turbine dynamos to furnish the current required with, at least, one spare unit, and, where practicable, all the power units in operation would deliver to main "bus-bars," or large electric conductors, in the station, and from the same to step-up transformers, which would raise the E.M.F. and reduce the current transmitted, thereby reducing the amount of copper required for transmitting the energy to a distance. For instance, the electric current may originally be generated at 2,000 volts, be raised by transformation to 10,000 volts or upward, at which pressure it may be conveyed many miles to points on the high-tension lines, and branched to points where the work is to be done, when, through step-down transformers, the pressure would be reduced to suit such work. For instance, one bank of transformers could reduce the alternating current to about 350 volts effective pressure, or about 500 maximum, and the current be transmuted by means of a rotary converter into direct current at 500 to 550 volts, and employed to operate electric railroads, the rotary transformer taking the place in the local station of the

boilers, engines and generators required for operation by steam.

In another case step-down transformers would be employed to reduce the pressure to 2,000 volts—for instance, on entering a city—and a local distribution circuit would be established at this pressure, which in turn would supply transformers at different parts of the city; for instance, in a building where considerable power is required, or at one point in a block where there are a large number of small consumers, the reduction for power purposes being generally to 500 volts, or to suit the motors employed, and for lighting purposes to 50 or 100 volts to suit the lamps installed. Synchronous motors could be operated at the full pressure of 2,000 volts from the distribution lines. At other points local stations would be established to supply three-wire city distribution. In other cases arc lights would be supplied from the high-tension current, the circuit for several lamps being supplied from one transformer; but in many cases a small transformer would be provided for each light. Cut-outs would, of course, be located in all the branches, and, in a low-tension system for local distribution, regulators would be placed to maintain a uniform voltage on each of the circuits.

The cost of steam-power depends upon the fuel consumed, the cost of the labor, supplies and repairs, together with interest on the investment and a contribution to a sinking fund, which will renew the plant in twenty to twenty-five years. The cost of fuel depends upon the kind of engine, which varies the quantity of water which must be evaporated into steam in order to supply such engine; also upon the kind of boiler, which varies the amount of water which will be evaporated per pound of fuel. There are so many conditions affecting the problem that separate calculations must be made for each case, or the probable result be inferred by consulting a number of large tables formed by progressively varying some one or more of the important conditions.*

* See tables of the writer in *Trans. Am. Soc. C. E.*, Vol. XII, p. 425, November, 1883; *Trans. Am. Inst. Elec. Engrs.*, Vol. X, p. 119, March, 1893; *ibid.*, Vol. XII, p. 464, June, 1895.

At this time we can only present briefly the calculations required for a single case.

Let it be supposed that 250 horse-power is to be delivered from a compound condensing-engine to a jack-shaft at higher speed. We assume that the friction of the apparatus as a whole will be 10 per cent., so that the mechanical efficiency is 90 per cent. All calculations are based on the indicated horse-power, or that measured by the indicator in the cylinder of the engine. Such indicated horse-power must, therefore, be 1 ÷ ·9, or 1·111 times the net horse-power. We assume that the engine requires 18 pounds of water per indicated horse-power per hour, and that the boiler will evaporate regularly 8½ pounds of water per pound of coal. The former quantity is larger than shown by some experimental results, but all that can be depended upon in regular work for variable power. The quantity last named is smaller than obtained experimentally, but fully as high as can be secured under average conditions. On this basis it will be found that, with coal at $3 per ton of 2,240 pounds, the cost of coal per net horse-power per hour will be 0·3465 cent. In manufacturing neighborhoods the cost per net horse-power hour for labor will be 0·17 cent, and from observation it is known that supplies and ordinary repairs will cost approximately 0·09 cent. If we allow for sinking fund, taxes and insurance 5 per cent. of the total cost of the apparatus, and also 5 per cent. for interest on the money invested, the cost per net horse-power per hour for this item will be about 0·2078 cent. The total cost per net horse-power per hour for coal, labor and supplies will, therefore, on this basis be 0·607 cent, and with fixed charges for interest, etc., added, be 0·815 cent, or for a year of 3,080 hours, $25.18. Similarly proceeding for an ordinary non-condensing engine of 10 horse-power, for which the whole of one man's time would not be required, the cost of the power will be found to be much larger, or about 2·45 cents per net horse-power per hour, or $75.46 for a year of 3,080 hours. With triple-compound engines, with units of not less than 500 horse-power, and very careful attention, the power can be obtained at the rate of 0·7

cent per horse-power per hour, or $21.38 per year of 3,080 hours. For every hour in the year the prices for the 10 horse-power and 500 horse-power engines will become $215 and $61 per net horse-power per year, respectively.

In ordinary practice, and particularly with variable power like that required for electric lighting and power purposes, the cost with compound condensing-engines, which are the best available for such a purpose, will be practically 1 cent per horse-power per hour, or 1 "horse-power hour," as it is called, or $30.80 per year for 1 horse-power continued for 10 hours per day and 308 working days in the year. At this rate, if 1 horse-power were operated throughout the entire year, or 8,760 hours, such horse-power would cost $87.60 per year. If, however, the power were variable, the yearly cost would be made up from the sum of the horse-power hours. It is found in practice that, by summing together the horse-power hours developed in ordinary electric lighting and power plants, the sum is in general not greater than if the maximum power were operated during ten hours per day for 308 working days, or, say, 3,080 hours per year. In this case each average horse-power would cost $87.60 per year, and each maximum horse-power $30.80 per year; but the average horse-power would be to the maximum horse-power as 3,080 to 8,760, so the total cost for the year of the entire power used would be the same as if the maximum power were employed for the shorter time, or the same as for what is called ten-hour power. We shall have occasion to refer to this point more at length in connection with the charges for water-power.

The cost of a water-power on streams reasonably free from ice and floating obstructions is due principally to the interest on the capital invested. Where the work is on a large scale, money can generally be raised for 5 per cent., and in making the calculations it is customary to include, in addition to this, 2½ per cent. for a sinking fund, 1½ per cent. for repairs, 1 per cent. for taxes and incidentals, or a total of 10 per cent. on the cost, with about 75 cents per horse-power for attendance, oil, etc. On this basis water-

power has been developed at a number of points in different parts of the country at a total cost corresponding to an annual charge of $8 to $12 per horse-power year. On the contrary, the water-power on the Merrimac, calculated on the same basis, has apparently cost about $30 per horse-power per year, or practically the same as steam power; but this cost includes certain rentals, which are in the main returned to the owners through the water-power company, which is itself owned by the mills, for which reason—and the fact that the real estate investments have been very remunerative—the actual cost of the power is considerably less than the apparent cost. It is, however, a fact that cotton mills can be operated profitably by steam-power without water-power, as shown by the considerable number of mills at Fall River and New Bedford, Mass., and elsewhere.

This preliminary discussion of the available facts will be of assistance in an examination of the outlook for companies incorporated to develop water-power and distribute the same electrically. The desirability of employing electricity for transmission to a distance is evident; but the decision of a number of eminent experts, in relation to the enormous developments of power proposed by the Cataract Construction Company at Niagara Falls, was that it was cheaper to distribute power locally by means of electricity than by the use of ordinary mechanical methods, and that the transmission of power to a distance could be part of the same system. In carrying out these views, units of 5,000 horse-power were adopted, each consisting of an electric generator and a direct-connected turbine of sufficient size to operate the same.

The cost of the work at Niagara Falls is not known to the speaker; but, continuing the discussion on general principles, it may be stated that, when the electric distribution of a very large power is undertaken, there are numerous distinctive features which reduce the cost. Work done on a large scale is cheaper as a general rule, and, moreover, the system of massing a number of large power units in one location makes it possible to do the work with one head-

race, one tail-race, and one series of wheel-pits, arranged in a single building. Under these conditions, it is thought that the hydraulic development for 80,000 to 100,000 horse-power—to include head- and tail-races, head-gates, wheel-pits, wheels and mechanical means of transmission from the wheels to the dynamos, together with necessary buildings, water rights, promotion expenses and the land needed for the work, independent of investment in extra property—should not cost more than $30 per gross horse-power, or $42.75 per net horse-power delivered. It is probable, however, that, to secure capital for such an enterprise, the original cost, represented by the securities issued, would be considerably greater than that stated. Moreover, it would not be practicable to develop at once the whole of such an enormous power, though the principal portion of the expense would necessarily be incurred at the outset. These considerations might raise the cost of a plant to $80 per net horse-power delivered.

At present prices it is considered that the cost of local electrical transmission will not exceed $40 per net horse-power. The total cost of plant would then, on this basis, be $120 per horse-power, and, allowing interest and fixed expenses as before, and $1.50 per horse-power for running expenses, would make the yearly cost $13.50 per horse-power. With the cost price as low as this, the power company might afford to sell at a profit power for $15 to $18 per year per net maximum horse-power, and the advantages to consumers would be very apparent, compared with twenty-four-hour steam-power, every hour in the year, for $61 to $88 per horse-power; or even ten-hour working-day steam-power at $30.80; or for coal at $1.50 per ton, say, $25 per horse-power per year.

Long-distance transmission in large units differs only from local transmission in requiring the employment of longer electrical lines and the use of step-up and step-down transformers previously referred to. The double set of transformers in large units will only cost about $11 per horse-power, and for a transmission of 20 miles at 10,000 volts, the copper in the line will cost about $21.50 per horse-

power. The total cost of the hydraulic and electrical development should not exceed $150 per horse-power delivered; so, calling the cost of attendance $2.50 per horse-power, and deducing the interest and fixed charges as before, the yearly cost would be only $17.50 per horse-power. Promotion expenses, the interest accumulating on bonds during construction, and other expenses incident to financing a large operation of this kind, would probably increase the cost greatly; still it would appear that the transmitted power might be sold for $20 or, at least, $25 per net horse-power in large units along the high-tension lines, which would still show an advantage over steam-power developed with coal at $3 per ton, and, at the worst, would stand on an equal footing with ten-hour steam-power developed in large units with coal at $1.50 per ton, as above stated.

Everything considered, it may be assumed that prices will be adjusted so as to make it advantageous for large consumers to use the power, and for high-tension lines to be run to their premises for that purpose. In a large city, however, it is not practicable to run high-tension lines except underground, and in connection with lines at lower tension, so that the distribution becomes complicated, and, without great care, quite dangerous. Two methods of distribution would be practicable—one to reach the power-houses of companies already installed and utilize their lines; the other to transmit the power locally through lines at lower tensions, though much higher than have been employed until quite recently. For instance, the 10,000 or 20,000 volts used for transmission could be transformed down to 2,000 volts, and these lines distributed to various points in a manner already described, to furnish current through other transformers for power and lighting purposes. If such distribution be attempted through companies already installed, as first assumed, their plants have already cost several times as much as we have estimated for the entire transmission plant, and interest and dividends must be paid on the whole capital invested; consequently, a saving of $5 or even $10 per horse-power would not be so large a proportion of the necessary total cost, including interest,

as to make a great difference in the charges to small consumers.

The attempt to establish a new distribution in a city already containing local companies for the same purpose, would necessarily meet with opposition, and, if forced through, the cost of making the distribution in the most economical way would be so serious that power in small quantities would still be so expensive that a very large use could not be predicted, in competition with ten-hour steam-power where coal is less than $3 per ton.

It is improper to calculate that all the power available can be sold at the prices now charged by the electric lighting companies, or for from 4 to 6 cents per horse-power hour instead of 1 cent for large engines and 2½ cents for small ones previously mentioned. Such companies necessarily charge large prices, principally on account of the large amount of capital invested and large operating expenses, independent of the cost of coal, and such prices are advantageous to small consumers from the fact that the power supplied is convenient, always available on demand, and costs nothing during periods of disuse. It is true that the uses of power are greatly extending in the larger cities, even at these prices, but the applications are generally in very small units, and the whole output for this purpose is very limited compared to the total amount of power used in the city, the majority of which cannot be reached without reducing prices nearly as low in some cases, and in others lower than the same work can be done by the steam engine. In making the comparison, the use of the steam plant, and particularly of exhaust steam in winter for heating purposes, must be considered.

These remarks apply principally to ten-hour working day power, or variable power for which the mean is a moderate fraction of the maximum. For steady power during twenty-four hours, the regular local companies could afford to make large reductions, and a special power branch of an electric transmission company give very satisfactory prices, for the reason that the number of hours' service does not increase the cost of water-power, whereas, the cost of steam-power is

practically proportioned to the number of hours it is used. Even, however, if the transmission company obtained prices approximately as high as are now charged by the electric light companies for very small powers, and made rates which appeared reasonable for twenty-four-hour power, it would still be unable to give satisfactory prices to the large amount of ten-hour power which goes so far in making up the aggregate, for the reason that it costs the transmission company practically as much for ten-hour power as for twenty-four, and charges must be made on that basis; that is, the transmission company could not reduce its price in proportion to the number of hours used, or sufficiently to compete with steam-power where coal is less than, say, $3 per ton. The same would be true for variable power continued through twenty-four hours when the average power is much lower than the maximum.

If the average powers during each hour be summed for the entire year, the horse-power hours for that time will, in most cases, be found not greater than if the maximum power were continued for ten hours per day during the working days in the year, as has already been stated. It follows, therefore, that the cost of the 3,080 horse-power hours, or for each horse-power per year, would, at 1 cent per horse-power hour, be only $30.80 per year, and, therefore, the charge for water-power, although available every hour of the year, must be sufficiently less than $30.80 per year to warrant the change.

It is interesting to note that these facts have been put in an entirely different shape, by publishing only the cost of average power, when the charges for transmitted water-power must necessarily be based on the maximum power. If the total cost of variable power be divided by the average horse-power throughout the year, the cost for each average horse-power will necessarily be very much greater than for each maximum horse-power, for the reason that the average horse-power is much less than the maximum power, and the prices of the two must be inversely proportional to each other, though the total cost remains the same. As stated, the cost of 1 horse-power for 308 days of ten hours each, at 1 cent per horse-power hour, is $30.80, and if the power

were continued for every hour in the year it would be \$87.60. The larger amount is 2·844 times the smaller, and the smaller 35·2 per cent. of the larger. For variable power with the average 35·2 per cent. of the maximum, the cost of each average horse-power would be 2·844 times as much as for each maximum horse-power, or \$87.60 per horse-power per year; but, on the other hand, the maximum horse-power, which is 2·844 times the average, would only cost for each horse-power 35·2 per cent. of the average horse-power, or \$30.80 per year; so the total cost per year, found by multiplying the lower power by the higher price, or the higher power by the lower price, will be exactly the same.

In the published account, previously referred to, only the very high prices based on the average horse-power per year are given, or those which correspond to the \$87.60 in above illustration; whereas, the lower prices are the ones applicable, corresponding to \$30.80 in the illustration given. The ratio of the average to the maximum power, or 35·2 per cent. in the above case, is called the "power factor." If such power factor were only 20 per cent., the cost of the average power would be five times as great as that of the equivalent maximum power; but as there would be only 20 per cent. as much power to pay for at the higher rate, the cost would necessarily be the same as if the maximum power were continued one-fifth of the time, and the cost of steam-power would evidently be only one-fifth of the cost of that continued for every hour in the year. The price of water-power must evidently be low enough to meet this cost, though actually available five times as many hours in the year.*

It may be necessary for a power transmission company to sell electric power by meter, but in such case the charge

* The calculations above presented are well illustrated by a contract recently made by the Cataract Construction Company with the Buffalo Street Railway Company. (See *Elec. Engr.*, August 5, 1896, p. 133.) The railway company is to be furnished 1,000 horse-power day and night for \$40 per horse-power per year, and apparently pays \$4.50 per horse-power for apparatus, making the total cost on basis stated in text \$44.50 per horse-power per year. If 1,000 horse-power of steam is actually used every hour in the year, it would cost, at 1 cent per horse-power hour, as stated in text, \$87.60 per horse-power per year, so the railroad company has made a good bargain even if 1,000

ERRATUM.

Foot-note below should read as follows:

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must be increased in the proportion above indicated, or 2·844 times in one illustration and five times in the other, making the result the same as if the maximum power were charged for. It is true that on electric light circuits it has been found that the plant need not be increased in as great a proportion as the increase in rated power of motors installed, for the reason that all are not operating at maximum power at the same time, so it would be possible for a power transmission company to make allowance for this in fixing prices. With the larger demands for variable power this could not take place. For instance, in the afternoon of a dark day the electric lighting plants and the electric railroad plants would both demand practically maximum power at about the same time. Moreover, the power factor of 35·2 per cent. is about that found in practice with large motor loads, as determined by the electrical output, so that the low average power of a large number of motors is already included. Consequently, with this power factor the hydraulic, generating and transmitting plants must be 2·8 times as large as would be required for average power, and the interest on the cost, which principally regulates the charges, be increased accordingly. With steam plants there is not so great a discrepancy, for the reason that the whole apparatus can be forced above capacity for a short time during the peak of the load, whereas the capacity of a water-power plant can only be increased by increasing the capacity of the wheels, and, consequently, of the whole hydraulic plant.

In conclusion, it may be stated that the investigation shows:

(1) That a very large water-power may be developed and

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horse-power is not used all the time. Additional power is to be furnished for $36 per horse-power, equivalent to $40.50, with fixed charges added as above. The load of the railroad, less 1,000 horse-power, must show a very low power factor; but if it be as high as 35·2 per cent., this represents, as explained in text, a cost for steam-power of only $30.80 per year per maximum horse-power, showing, as stated in the paper and emphasized in the conclusion of the first part, that 24-hour power can be furnished advantageously by transmitted power, but that questions arise for 10-hour power or variable power of an equivalent number of horse power hours.

the power transmitted locally with advantage, in competition with steam-power, even where fuel is cheap, if the cost of construction be kept within reasonable limits.

(2) That transmission of power 20 miles from a waterfall is practicable, even in competition with steam-power from cheap fuel, if the power is utilized for twenty-four hours, or in large units, or delivered at high tension on the premises of the manufactory and distributed under conditions less exacting than those which obtain in a large city.

(3) That when fuel is $3 per ton or over, electric transmission is very generally applicable.

The lecture was illustrated with a large number of lantern slides, showing the distinguishing features of electrical transmission installations in different parts of the country. The speaker stated that the business was advancing with rapid strides, and that the future growth was very promising.

The speaker continued: It is considered impossible within reasonable compass to even give a list of the principal plants of this kind, but brief references will be made to a few of the same for the purposes of illustration.

The possibility of electric transmission of power was foreseen by very many parties in different parts of the world, and some comparatively unimportant applications were made from time to time, but an historical work would be necessary to give the same proper credit. The growth of the business as a commercial industry practically began with the Electrical Exposition at Frankfort, in 1891, where electric energy was transmitted from a waterfall at Lauffen, 108 miles away. The cost of this particular plant was so great that the power developed at Frankfort really cost some four to five times as much as it could have been developed for with steam machinery on the spot; but the installation settled a large number of doubtful questions and warranted the application of such transmissions in evidently favorable locations, thereby bringing about a reduction in the cost of apparatus and opening a wide field for such enterprises.

The Westinghouse Electric and Manufacturing Company are understood to have installed the first commercial long-distance transmission in this country, and this firm has carried out works of the largest magnitude that have been undertaken in any part of the world, as instanced by the 5,000 horse-power biphase alternating generators at Niagara Falls. The General Electric Company has probably been doing the greater volume of business during the last few years.

The Westinghouse Company, about the year 1890, or before the Frankfort Exhibition, arranged to light the city of Portland, Ore., by power generated at the falls of the Willamette River, at Oregon City, 14 miles distant. The fall is about 40 feet. Victor wheels of 300 horse-power, through intermediate shafting, operate two alternating-current dynamos. The current generated at 4,000 volts is received in Portland at 3,300 volts, and reduced by transformers to 1,100 volts for distribution through the city to ordinary transformers, by which it is reduced to 50 to 100 volts.

Another early plant installed by the Westinghouse Company was at Telluride, Col., where power is furnished the Gold King Mill from a waterfall nearly 3 miles distant, but on the other side of a mountain 2,500 feet high. In this case a Pelton wheel, receiving water through a 2-foot steel pipe, under a head of 320 feet, drives an alternating-current generator, which in turn operates an alternating-current synchronous motor of 100 horse-power at the mill. The pressure is 3,000 volts.

The Westinghouse Company has also a single-phase transmission plant in the mountains at Bodie, Cal., where the ruling price of wood has been $10 per cord for years. Sufficient water is obtained from Green Creek, on the north slope of one of the spurs of the Sierra Nevadas, to operate, at a head of 355 feet, four 21-inch Pelton water-wheels. The transmission is made at 3,530 volts, without transformers, to a distance of 12½ miles. At present only one 120-kilowatt synchronous motor has been installed.

The same company has an interesting plant at Pomona,

Cal. It consists of a Pelton water-power plant and a Westinghouse single-phase alternating-current transmission plant, in which the generators supply current to step-up transformers, raising the pressure to 10,000 volts, and transmitting current on separate circuits to Pomona, 13¾ miles distant, and San Bernardino, 28¾ miles distant, where the pressure is reduced by transformers to 1,000 volts for local transmission, and finally to lower pressures to supply incandescent lamps. The water is supplied through a pipe 30 inches in diameter and about 2,000 feet long, which has sufficient capacity for 1,882 horse-power at 390 feet head, only about one-third of the power being at present required. The efficiency of this transmission is over 75 per cent., and, experimentally, the two lines have been connected so as to make a circuit 85 miles in length, corresponding to a distance of transmission of 42½ miles, which distance is greater than has yet been covered by any transmission since the Frankfort experiments. The efficiency over this long line proved to be over 60 per cent.

One of the earlier installations of the General Electric Company was at Taftsville, Conn., where the Ponemah Mills are driven electrically by power from water-wheels at Baltic, 4½ miles distant. The electric plant consists of two 250-kilowatt three-phase generators, and two 250-kilowatt synchronous motors, wound for 2,500 volts.

At Columbia, S. C., there is a local electrical transmission plant, the turbines and generators being situated in a gorge and the mill on a bank near by. Victor turbines connect directly, through horizontal shafts, to two 500-kilowatt General Electric three-phase generators, which, on account of the low head of water, are built to operate at a speed of 108 revolutions per minute, and, consequently, are of colossal size, each weighing 10,000 pounds, with armatures 10 feet in diameter. In the mill there are sixteen induction motors of 65 horse-power each, severally hung from the ceiling, and driving separate sections of line shafting. The speed of the motors is 535 revolutions per minute.

The General Electric Company has erected a transmission plant at Lowell, where three-phase generators, operated

by water-power, furnish alternating current to sub-stations 9 and 15 miles from the power-house, from which direct current is delivered to operate the railway system between Lowell and Nashua. The transmission is at 5,500 volts, which in the sub-stations is reduced in potential by transformers, and supplied as direct current to the trolley lines, at 550 volts, through rotary converters.

The same company has installed, at Portland, Ore., three 450-kilowatt three-phase generators, with armatures mounted on vertical shafts, each of which can be connected directly to a turbine operating the same at 200 revolutions per minute. These turbines can, however, be disconnected, and larger ones connected by belt during high water, when the head is greatly decreased. Current is generated at 6,000 volts, which is transmitted the whole distance, and, at a local station at Portsmouth, is, in part, transformed down and used to operate two 400-kilowatt rotary converters, which furnish current at 500 volts for operating street railways. Light is also furnished and motors operated on the Edison four-wire system.

The General Electric Company has also made a very interesting adaptation of three-phase transmission to operate the Silver Lake group of mines, lying about 4 miles southeast of Silverton, Col., at an elevation of 12,300 feet above the sea. The mill was formerly operated by steam-power, coal being brought by a zigzag track up the mountains, and, by the time it reached the furnace, cost $8.75 per ton. The plant is now operated by water-power brought from the Animas River, above Silverton, by a 3 x 4 foot flume 9,750 feet in length, which carries 2,350 cubic feet of water per minute. The head of water is about 180 feet, which is used to operate two double-nozzle Pelton water-wheels, 4 feet in diameter, in a small building in the valley below. The conductors are No. 3 B. & S. bare copper wires, supported on a pole line extended up the mountain passes for 3 miles through the rugged country, spanning at one point a distance of 275 feet across a chasm. The transmission is made at a pressure of 2,500 volts. About three times as much power is now available as when the

steam engine was employed, so that the change has been a great improvement in efficiency and economy.

A notable transmission system has recently been completed to supply light and power at Sacramento from Folsom, on the American River, 24 miles distant. The State, mostly with prison labor, developed the water-power, the water being first used for power purposes in co-operation with the Sacramento Electric Light and Power Company, and then for irrigation. There is a massive dam of granite, 650 feet long, 89 feet high in the center, 87 feet wide at the base, and 25 feet wide at the crest, with flash-boards 6 feet high, which, at high water, can be lowered in a recess in the crest of the dam, and raised when desired by hydraulic pistons. The water is conducted in a canal 2 miles long to the power-house, where a fall of 55 feet is available. There will be installed four pairs of wheels of the McCormick horizontal shaft turbine type, each pair of 1,260 horse-power at 300 revolutions. Four General Electric three-phase 750 kilowatt generators are operated at 800 volts, which is raised to 11,000 volts through step-up transformers, each of 265 kilowatts capacity. The sub-station is centrally located in the city of Sacramento, and contains step-down transformers and 1,000 horse-power in three synchronous motors. These motors drive arc lighting and railway machinery. The power is distributed through the city by a low-tension three-phase four-wire Edison feeder and main system, the potential regulators being located in the sub-station. Street cars in Sacramento have been operated by transmitted power since July 14, 1895.

The Niagara Falls hydraulic and electric plant, with which the honored Chairman of your Lecture Committee, Dr. Coleman Sellers, has been so prominently connected, is notably much the largest that has yet been undertaken, it having been decided, as previously stated, to use the entire power developed for the generation of electric current, and operate all local manufactories, as well as those at a distance, by electric transmission. The arrangement is distinctive, as the water, instead of being conducted in a canal to a power-house and discharged at a low level directly, is received by

the turbines in a deep pit about a mile back of the falls, and discharged through a tail-race tunnel extended northward under the village of Niagara Falls, and coming out of the bluff near the lower water level. Each unit is 5,000 horse-power, or larger than either of the entire plants previously referred to. It is intended to instal ten such units in the first wheel pit, though the tunnel has sufficient capacity for about 100,000 horse-power. The head utilized is about 140 feet.

The turbines were designed by Messrs. Faesch & Pickard, of Geneva, Switzerland, and built by I. P. Morris & Co., Philadelphia. They operate at 250 revolutions per minute. The governor was designed by the same parties. The turbines are necessarily near the bottom of the pit, and are connected with the head-race by steel penstocks. The generators are at the ground level, and are connected directly with the turbines by steel shafts made up of tubes 38 inches in diameter, reduced to 11-inch solid shafts at the journals. To secure regulation, a heavy fly-wheel is necessary to give the governor time to act. A separate fly-wheel was made unnecessary by the suggestion of Mr. Forbes, the consulting engineer, of England, that the fields of the generators be made to revolve instead of the armatures.

The generators were designed and constructed by the Westinghouse Electric and Manufacturing Company. The revolving field consists of a heavy steel ring, 11 feet 6 inches in diameter, with internal pole pieces and bobbins, connected by means of an upper disc with the shaft which extends through and above the stationary armature. The generators deliver biphase alternating current at 2,000 volts, with a periodicity of twenty-five cycles per second.

The total weight of the revolving parts is 152,000 pounds, of which about 79,000 pounds are included in the revolving field above referred to. This enormous weight is practically balanced by the water-pressure, the remainder being supported in an ordinary collar thrust bearing. Twin turbines are employed. The lower disc of the case carries interior guides for the lower turbine, which latter is supported outside the guides by a revolving disc below, receiv-

ing no pressure, while the upper stationary disc for supporting the guides for the upper turbine is perforated and permits the water-pressure to reach the under side of the revolving disc carrying such turbine outside the guides. In this way the greater part of the load, and, at times, the whole of it, is water-borne and the thrust bearings only receive the residual up or down strain. The gates are ring-shaped, and are moved up and down outside the discharge openings of the wheels by the governor, an arrangement not used or favored by turbine manufacturers in this country, though apparently operating satisfactorily in this case.

Water for power is supplied through two wheels of 1,100 horse-power each to the Niagara Falls Paper Company, and discharged into the tunnel. About 2,000 horse-power is being electrically supplied to the Pittsburg Reduction Company, and used in the manufacture of aluminum, the bi-phase alternating current being transformed in four large rotary converters to direct current. The uses of power in this establishment is to be greatly increased. About 1,000 horse-power is supplied to the Carborundum Company, which manufactures an abrading material used as a substitute for emery. This process being a heating one, the alternating current is employed directly, being simply reduced in pressure by a special regulator and static transformer to between 100 and 200 volts. About 1,500 horse-power is also being furnished through rotary converters for the operation of electric railroads, and it is understood that other applications will soon be made. It is also anticipated that a large block of power will be transmitted to Buffalo for various uses in that city.

SOME RECENT WORK ON MOLECULAR PHYSICS.*

By Reginald A. Fessenden,
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My first thought on writing to your secretary that I would lecture on molecular physics, was that I should review briefly the more important of the recent advances in that branch of science, but I was not long in reaching the conclusion that this would be inadvisable. For, to those of my audience who might be specialists in that direction, the greater part of what I should say would merely be a *résumé* of the recent history of the subject, while, in order to make it interesting to those who were not, an amount of preliminary description would be necessary which would leave no time for touching on more than one or two points.

I have, therefore, thought it best that I should take up certain phenomena with which we are all more or less acquainted, namely, the behavior of those metals which are in every-day use, and show how certain theories of mine may be applied to explain them.

Some of the theories which I shall develop to-night are not yet universally accepted as articles of scientific faith. Therefore, they should be received with a certain reservation until further evidence confirms them. On the other hand, I should say that they need not be viewed with distrust; for in no case is any theory introduced which has not received the sanction of some at least of the foremost specialists in whose field it belongs.

This subject, the molecular physics of solids, is one to which I have devoted special attention, and to which I have contributed some original work. I trust that I shall be able to bring to your notice certain new relations which will interest you, and which may help to give a more com-

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* A lecture delivered before the Franklin Institute, February 14, 1896.

plete realization of the atomic theory of matter—relations which are, moreover, of great practical importance.

To begin at the beginning, we should commence with the ether. That subject is now so buried beneath a pile of mathematical theories, each one incompatible with observed facts at some one or more points, that I shall not disturb it to-night, but confine myself strictly to the atom and molecule.

First, let us try to get a more or less exact idea of the manner in which solid bodies are built up from atoms; how far apart, and in what manner, the atoms are spaced; how they are arranged; and the nature of the forces acting between them.

A description of the methods by which the diameter of the atoms has been calculated has, for so long a time, formed a portion of our text-book and lecture knowledge that I will not go over the ground again, but will simply give a list of the more important determinations of this constant. These are:[1]

Heat of combination of copper and zinc, 10^{-8}.

Heat of vaporization and surface tension of water, $\cdot 7 \times 10^{-8}$.

Viscosity of gases, 6×10^{-8} to $2\cdot 9 \times 10^{-8}$.

The mean is about 10^{-8} centimeters, and in our calculation we will take the distance between the centers of two atoms of silver (the silver being in the solid state and at ordinary temperatures) as 10^{-8} centimeters.

The next question is: "How much of this space is occupied by the silver atom itself?" From Van der Waal's equation, which, though it is not exact, seems to give a fair

[1] It will be noted that I have rejected determinations depending upon measurements of the dark space in soap bubbles. This is for the reason that I do not consider them of any value for the purpose. The assumption made that the conductivity of a film is proportional to the thickness, even when the film is but a few molecules, or even only 1 molecule, thick, I regard as extremely improbable, and, indeed, it is possible to prove that it is incorrect. In fact, it is my opinion that one of the greatest hindrances to the development of molecular physics has been the undue importance which has been attached to some mathematical theories, based, so far as they have a foundation, upon surface-tension experiments.

approximation to the facts, we find that when a substance is at the critical temperature and volume, the space which the atoms would occupy if they were all touching each other is one-twelfth that occupied by the substance ; consequently, the distance between centers of adjacent atoms cannot be more than 2·3 times the diameter of the atoms themselves. But below the critical temperature, the coëfficient of expansion is very great, so that the atoms in the solid state must, at ordinary temperatures, be much closer than this. In fact, if we take the values of the density of the molecules of alcohol, ether, carbon disulphide, etc., as calculated by Nernst, and compare them with the densities of the substances themselves in the fluid state, we find that the ratio of the volumes is only one-third instead of one-twelfth; *i. e.*, the distance between centers of molecules is only 1·5 times the diameters of the molecules. Taking into account the still farther contraction in passing into the solid state, we find that it is improbable that the distance between centers is more than ·3 times the diameter of the atom.

Again, starting from the solid state, if we consider the experiments of Dewar, we see that the electrical resistance of metals varies with temperature in such a manner as to probably become zero at the absolute zero of temperature. Both electrical resistance and expansion vary very roughly, linearly, with temperature; and the expansion for most of the metals between absolute zero and their melting points is, so far as we can judge, about 2 per cent. linear. Unless, therefore, we are prepared to make the supposition that the relation suddenly changes at low temperatures, we must suppose that there is no very sudden change of large amount in the coëfficient of expansion of metals near absolute zero.

Consequently, we see that the mean distance between centers of adjoining atoms is probably between 1·02 and 1·3 times the diameter of the atom itself. In other words, the distance between any two atoms is between $\frac{1}{50}$ and $\frac{3}{10}$ the diameter of the atom itself.

There is one difficulty, however, in accepting this conclusion. This is the fact that two substances can combine to

form a new substance which is smaller than either of its constituents. For example, if we add to 45·4 cubic centimeters of potassium its chemical equivalent of chlorine, which would by itself occupy about 18 cubic centimeters, we get as a product an amount of chloride of potassium occupying but 37·4 cubic centimeters, 15 per cent. less than either. This, at first sight, is very astonishing, and many theories have been suggested to account for it; such, for instance, as that the atoms are capable of existing in more than one state, and that the size

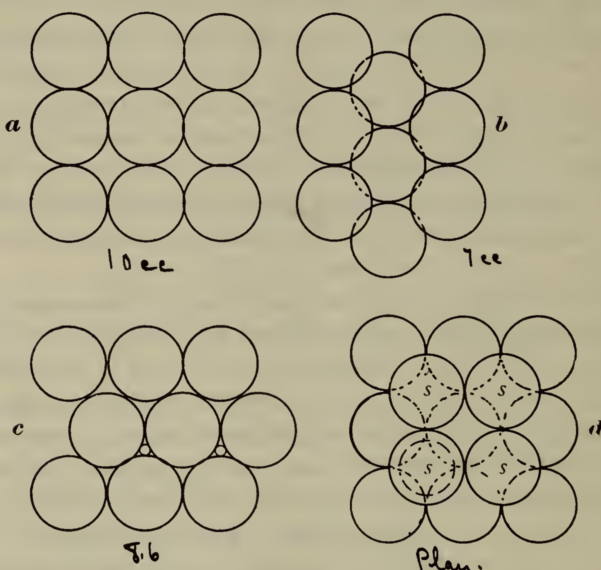

Fig. 1.

of the atoms in one of these states may be half or a quarter the size it has when the atom is in another state. No such hypotheses are needed, however, for the results follow, as I shall shew, from simple geometrical considerations.

Suppose we have a metal bar made up of atoms, and the metal is thoroughly isotropic, and does not split more easily in one direction than in any other. Then the atoms must occupy relative positions as shown in *Fig. 1a;* for if they were arranged differently, the bar would show cleavage planes. If, however, we roll it under great pressure, then the atoms

will be forced to take up positions as shown in *Fig. 1 b*, and it is now stronger in one direction than in another, and it is readily seen that the space occupied by the metal is now only

$$\sqrt{\tfrac{1}{2}},$$

or 70 per cent. of what it was before. It is, of course, impossible for us, in practice, to increase the density of a metal to this extent, for the metal flows with such great pressure; but this is the theoretical limit.

In the spaces, *s s*, here (*Fig. 1 d*) there is still left room for an equal number of atoms having a diameter $\frac{4}{10}$ that of the potassium atom.

Thus, we see that potassium could combine with an equal number of atoms of a monovalent element having an atomic volume 3, to form a new compound having an atomic volume of only 31·7. Therefore, instead of the contraction experienced in the formation of KCl being so great as to necessitate a new theory, postulating novel and remarkable properties of the atoms, we see that we might be prepared, from simple geometrical considerations, to find potassium compounds showing still greater contraction than is actually observed.

The actual contraction experienced in the formation of KCl can be accounted for by making the supposition that the atomic volume of chlorine is 18. The lowest atomic volume thus far measured is 21, at — 80°, but this was in the liquid state, and in the solid state it is probably less. Moreover, examination of the curve of atomic volumes and weights leads to the same conclusion.

I have elsewhere[2] calculated the theoretical shrinkage of NaOH, KOH and NaCl, and find that in all cases it comes within 5 per cent. of that actually observed, and is always on the right side.

This fact leads us to a very interesting result.

These calculations were made upon the supposition that the volume occupied by an atom is spherical. The fact that the calculations come out so closely seems to show that

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[2] *Science*, March 3, 1893.

whatever the actual shape of the atoms themselves, the space which one atom occupies to the exclusion of another atom cannot differ very greatly from a sphere. When we reflect that each atom, when not at absolute zero, keeps other atoms from touching it by virtue of its kinetic energy, and that this repulsive force must therefore be exercised in all directions, we have a reason why this should be so.

In all my work on molecular physics I do not think I ever came across anything which gave me so vivid a sense of the actuality of the atoms as this fact, that the observed contractions in the case of these salts is just what it would be if the atoms were arranged as solid bodies, nearly touching one another, and of approximately spherical shape.[3]

This same tendency of the atoms when stressed to assume an æolotropic state is the chief reason why, so far, we have been unable to obtain any accurate data upon which a complete theory of matter could be founded. I do not think it is generally appreciated how inexact is our knowledge of the physical constants of solid bodies. There are very few constants, indeed, as will be seen from the tables, given below, *Fig. 8*,[4] which we know to within 20 per cent. This is because these constants depend largely upon the physical manipulation which the material tested has undergone. Even winding a wire on a reel will, in some cases, markedly change its electrical conductivity, as dynamo builders are aware, and the difference in tensile strength of hard-drawn and annealed material is too well known to need emphasis.

It was Mathiessen, I believe, who first pointed out that a wire which had been drawn several times was no longer

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[3] I have since made up a few crystals by piling together small paraffine balls, whose sizes were proportional to the sizes of the atoms in the crystalline substance, the different sizes of balls being used, of course, in the same proportion as the corresponding atoms in the substance. In each case the angles thus determined experimentally were very close to those of the actual substance.

[4] The variations in the tensile strengths are not given, as they depend so largely upon the size of the piece tested and on other circumstances mentioned below. The difference amounts in some cases to 200 per cent.

a solid cylinder, but really a nest of concentric tubes. *Fig. 2* shows two sections of such a wire.

It is possible, I understand, in certain cases where a wire has been drawn a number of times without sufficient annealing, actually to peel off these tubes one after another like the coats of an onion.

Mathiessen also supposed that, in drawing, the inner tubes were sometimes broken while the outer ones still held, and accounted for some anomalous results he had obtained by this theory. The reason of this curious formation is less known than the fact. It is evidently due to the piling up of the stress at certain points. This is analogous to the

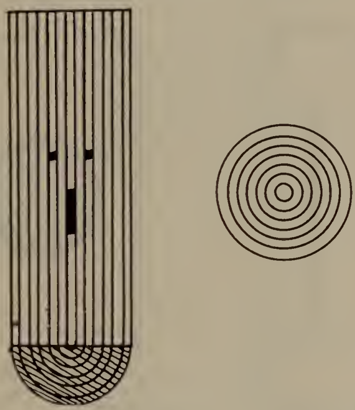

FIG. 2.

case met with in the bending of pillars. It may be proven that if we put a weight on a pillar it may not bend out in a bow, as we might suppose at first sight, but that the pillar divides itself up into segments, as shown in *Fig. 3*.

As I have said, there is an analogy, but it is difficult to see how it is to be applied to the case of a wire compressed uniformly all around. If we suppose, however, that, in the drawing, the die and wire have dissimilar cross-sections, it is not difficult to see, though I have not tried to work it out mathematically, how this may produce the result; for in that case every portion of the wire, as it passes through the die, would act as a short column, *Fig. 4*, and moreover, when the localized stress had once produced a non-homogen-

eous strain, the latter would tend to propagate itself even when the pressure was nearly uniform. Other examples of this effect are the cleavage of slaty rock, and the effects mentioned by Tyndall in his much (and I believe unjustly) abused book on diamagnetism. It will be remembered that by simply pressing some paramagnetic substances, they become diamagnetic, and he connected the effect with much reason with the presence of cleavage planes.

I have noted a phenomenon which would seem to show that the same nodal piling up of stress takes place when a bar is pulled apart. Going one day into the testing laboratory of Messrs. Hunt & Clapp, I noticed the assistants

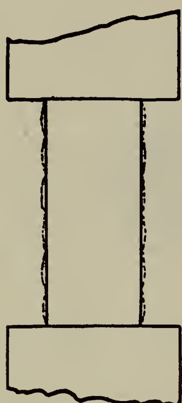

FIG. 3.

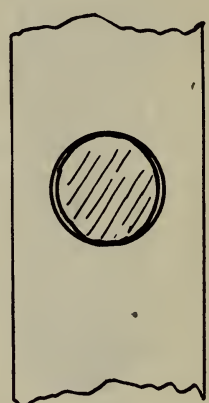

FIG. 4.

pulling some flat bars of aluminum. I placed myself so that the light from a window should be reflected to me from the surface of the bar which was being tested, expecting to see evidence of a hollow at the point where the bar would finally break. Instead, what appeared was this: two small hollows appeared, one near each fastening clamp. As the strain on the piece slowly increased, two more hollows formed. They crept together like ripples on water (each individual hollow remaining in its original position, but the new ones forming continually), until the two sets finally met in the middle, and, at the instant of meeting, the bar parted (*Fig. 5*).

It might appear possible to get rid of this æolotropic state by annealing. To a certain extent this is true, but other difficulties are introduced. It is impossible, by the means ordinarily used, to anneal a specimen without introducing impurities. Gases from the flame or from the air, or carbon from the coal, may be absorbed.

Now, when we speak of a substance as chemically pure, we are accustomed to consider it as pure enough for any physi-

FIG. 5.

cal test. Yet this is not so; for quantities of substances absolutely inappreciable in chemical work affect the physical properties very greatly. Even Stas's silver would be unfit for physical tests, though in a perfectly annealed form; for, as Chatelier has shewn, the occlusion of a quite imperceptible weight of hydrogen changes the melting point of silver 39° C., and also changes the electrical conductivity and temperature coëfficient markedly. (Other

observers say that it is the oxygen-occluding silver which gives the false melting point. In either case the fact to which attention is called, *i. e.*, that small quantities of gas affect the melting point, is correct.)

Roberts-Austen's experiments on the tensile strength of gold alloys give a similar result. He shewed that $\frac{2}{10}$ of 1 per cent. of bismuth reduced the tensile strength of gold to one-twentieth of the value for the pure metal, and its elongation from 40 per cent. to zero.

At the same ratio the $\frac{1}{100}$ of 1 per cent. of bismuth would affect the tensile strength 6 per cent. Many other examples may be found in Roberts-Austen's beautiful researches.

Now, it might appear impossible to get rid of all of these discrepancy-producing phenomena, although means will readily suggest themselves for getting rid of some of them. Yet I believe it is possible. A good many years ago (in 1879, I believe), Mr. Edison, in his work on the incandescent lamp, had examined the effect on platinum and iron wire produced by heating them, in a vacuum, to a high temperature. His results had not the immediate practical value hoped for, but I believe that the method will prove of the greatest scientific importance. He found that, by this treatment, the pitted and cracked wires which had been produced by annealing in the air took on an entirely different nature. The cracks disappeared, the pits vanished, the soft, lead-like wires became springy, and the dull surface turned to a lustrous one. Both tensile strength and rigidity were greatly increased. This method of treatment is, I believe, the solution of the problem—"How to attain a standard physical state in metals, so that they can be used in physical work." If we take a wire, full of cracks and non-homogeneous through hard drawing, with occluded gases, and mixed with oxide, nitride and hydride (if this be possible), then, on heating it sufficiently in a high vacuum, as we do the filament of an incandescent lamp, we may drive off the occluded gases, decompose the nitride and hydride and compact the metal. By heating again in excess of hydrogen, and keeping the metal near the melting point we can reduce the oxide, and then further pumping will remove the hydrogen.

If the wire be pure to begin with, with the exception of admixture with gases, specimens can always be produced in a similar state and may be expected to give the same results as any other wire of equal purity and treated in the same way. In some experiments I have made, very concordant results were obtained.

It is evident that we require a "standard physical state," to which all materials should be reduced before being tested. If some chemical firm, or some scientific body, could furnish elements in a high degree of purity and in such a standard state, the theory of molecular actions would, in a few years, reach a state which cannot, with the present indiscriminate way of working, be reached in a century, if ever; for then, if one scientific worker, like Dewar, should make experiments on the electric conductivities of metals or their thermo-electric properties at different temperatures, and some other experimenter should work on the tensile strengths of the same substances, the results could be compared, and any possible connection between them could be detected. At present it is idle to compare such results since the materials differ so much.

I would, therefore, propose that *the "standard physical state" of metals be defined as that state which is produced by heating the metals in a vacuum for one hour at a temperature as close to the melting point as possible, and that all physical tests, so far as possible, be made with material which has been treated in this manner.*

In making tests for tensile strengths we come upon another source of discrepancy. This is due to the fact that when we test a metal we have a different material at the end of the test from that with which we started. By the very act of pulling apart, the material has become hardened. Theoretically, a perfectly homogeneous material should have no elongation and very little tensile strength, no matter how strongly its particles are held together by cohesion when test pieces are taken having cross-sections which are not very small, say, not less than the $\frac{1}{100}$ of a square inch; for if the metal remained homogeneous while being pulled apart, then any small inequality in applying a stress would

start a crack, and at the edge of this crack the stress would be piled up, and so the crack would continue and increase until, at length, the metal broke with but a small fraction of the weight it would support if the stretching hardened it. Therefore, for testing we must have standard sizes.[5] It is for this reason, probably, that the tensile strength of diamond, which, as we shall see is held together with a much greater force than the best steel, does not appear on actual test to be so great. But it is evident that if we could in any way make the stress perfectly uniform we should find that the diamond was much the stronger of the two.

In the case of diamond we cannot do this, but in the case of quartz we can; for if we draw the quartz out into a long, thin thread, by the method devised by Boys, then the strain will be applied very evenly at any point located a few hundred diameters from the ends. Therefore, though the tensile strength of quartz in large crystals is very small, in fine threads it has a tensile strength not much inferior, I believe, to a fair quality of steel when test specimens of the latter are taken having fairly large cross-sections.

Thus, there are good reasons for believing that if materials be arranged in two lists, one containing the materials in their order of hardness, and the other the same materials arranged in the order of their tensile strengths, the order in both lists will be found identical.

A most interesting question is this: "What is the nature of the force which holds the atoms of a metal together, and why is one metal stronger than another?" In other words: "What is the cause of cohesion?"

The theory which I now present to you was first published by me in August, 1891.[6]

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[5] The millimeter diameter wire has been used in much important work, and is desirable for many reasons.

[6] *Electrical World; idem*, August 22, 1891; *Science*, July 22, 1892, and *idem*, March 3, 1893. It is only fair to say that the substance of the first three papers and the greater part of the fourth was completed in a more extended form in 1890, but I was unable to find a publisher. From the letters notifying me of the rejection of the manuscript, I learned that the chief objection was the presence of the double charge on the atom, which was considered impossible on conducting atoms. It has since been shown

Briefly, it is this, that the force of cohesion is due simply to the ionic charges of electricity on the atoms.

For suppose that we consider a wire, taking a cross-section through it; then we have two layers of atoms, one on each side of the cross-section plane, and if we know the charge on an atom, we can calculate approximately the resultant attraction. This, in the following manner:[7]

From Rayleigh's experiments on the electrolytic equivalent of silver, we find that the atoms of a cubic centimeter of silver have a total ionic charge of about 1,000 coulombs. As the diameter of the silver atom is about 10^{-8} centimeters, there are 10^{24} atoms in a cubic centimeter. Therefore, the total quantity on a single atom is about 10^{-20} coulombs. On a single layer 1 square centimeter in area, the quantity will be 10^{-4} coulombs.

Considering, then, the two adjacent layers as two plates of a condenser 10^{-8} centimeters apart, and charged with 10^{-4} coulombs of electricity (supposing for convenience that the charges act as if concentrated at the centers of the atoms), we get for the force required to separate the two layers, 44×10^5 dynes.

Now, according to Wertheim, the actual value for the tensile strength of silver reduced to a cross-section of 1 square centimeter is 37×10^5 dynes, which, it will be seen, is quite as close an agreement as could be expected, considering the uncertainty as to the exact size of the atom.

How would the tensile strength depend upon the size of the atoms on this theory?

Consider my table of the elements here presented, *Fig. 6*,

(Burton, *Phil. Mag.*, **38**) that the atoms must necessarily be non-conducting. Moreover, though I was unaware of it at the time, the double-charged atom had previously been used by Helmholtz for his chemical theory. The writer was, however, the first to extend the province of the electrically-charged atom from its purely chemical functions to the phenomenon of cohesion and its allied physical effects. Since then other workers have entered the same field, *i. e.*, Chattock, who has given us a very satisfactory theory of dielectrics; Kelvin, who has given us the piezo-electric theory of quartz which bears his name; and Richartz, who has worked on the subject of magnetism.

[7] This calculation (of the atomic charge) was first made by Stoney, Brit. Assoc., August, 1874. See also Lodge, Brit. Assoc., 1885.

which I have found very convenient, more especially so as the discovery of the new elements has not necessitated any change in its construction. On one side of the prism round which the table is wrapped, we see all the metals which are used in the mechanical arts. These are the only metals about which we have data. The table, *Fig. 7*, shows

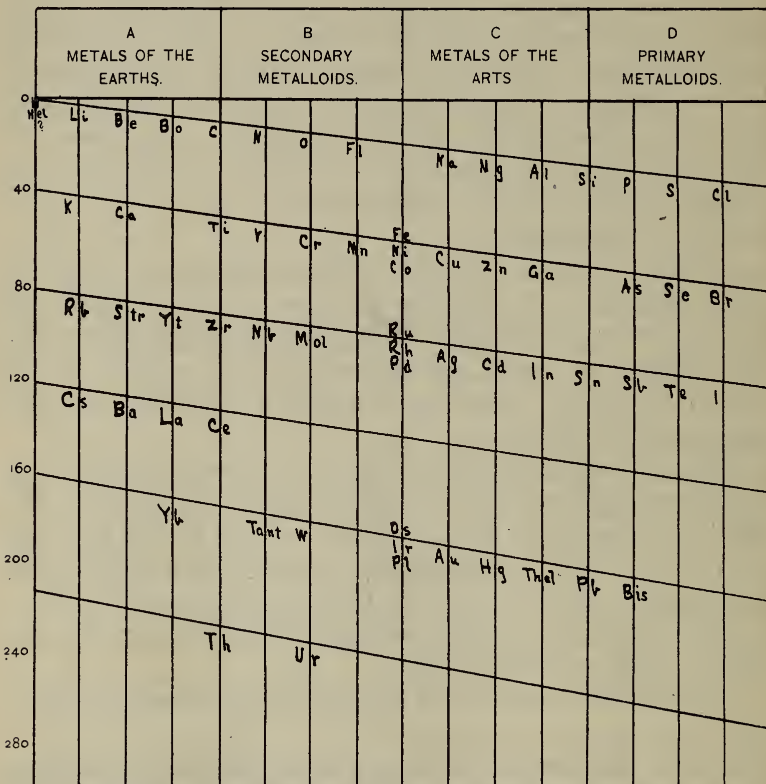

FIG. 6.

their atomic volumes. It will be noticed at once that those metals having the smallest atoms are the strongest. This is better shown in the following table, *Fig. 8*.

Suppose now we take two wires made up of atoms, but the atoms in one wire twice the diameter of those in the other. Consider the charges as before, concentrated at the

centers of the atoms. Since the charge on each atom is the same, and the smaller atoms are twice as close together as the large, twice as much work will be done in shearing the rod made of small atoms through a certain angle as with

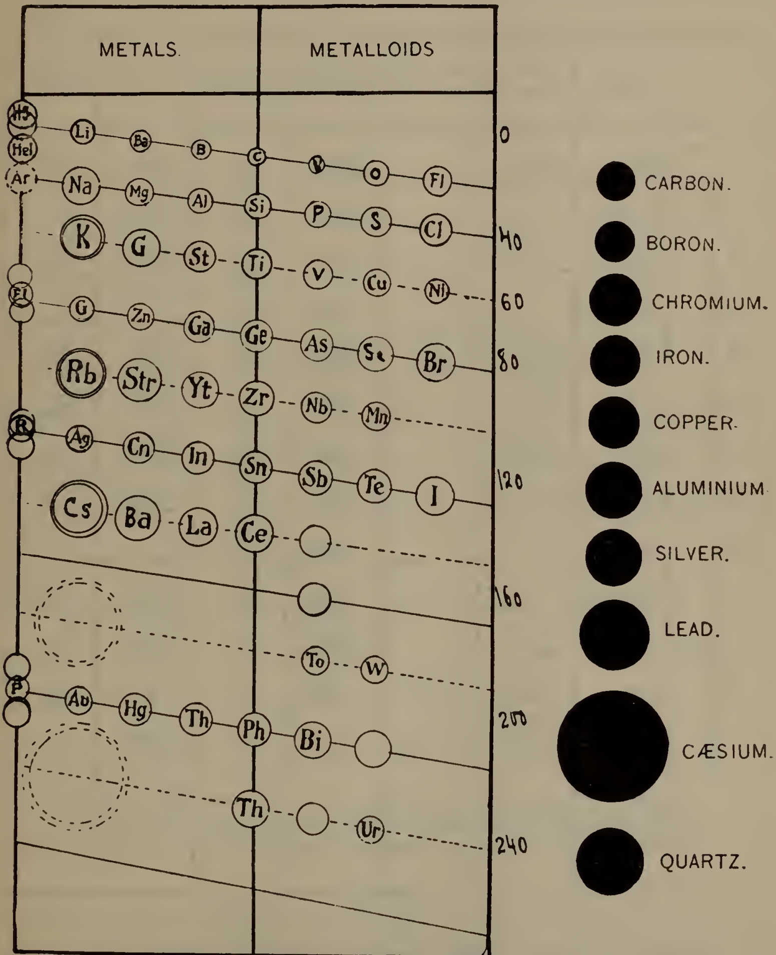

FIG. 7.

the rod of the large atoms. Moreover, in the smaller rod there will be twice as many atoms to be sheared; therefore, the force required to produce a given shear, *i. e.*, the rigidity, will vary as the inverse fourth power of the atomic diameter,

or as the $\frac{4}{3}$ power of the atomic volume.[8] The same will hold for Young's modulus.

We have not taken into account the fact that the rigidity and Young's modulus vary with temperature, so that it is only fair to compare metals when at equivalent distances from

	METAL TESTED.	TENSILE STRENGTH	GREATEST DIFF. %	YOUNG'S MODULUS.	GREATEST DIFF %	RIGIDITY $\div 10^{-6}$	GREATEST DIFF %
7.1	IRON.	65		2000	14	750	16
6.7	NICKEL.			2240	6	760	
7.1	COPPER.	41		1220	22	430	16
9.2	PALLADIUM			1050	14		
9.2	ZINC.	15.7		930	31	350	20
10.2	SILVER.	29.6		740	17	280	26
10.2	GOLD.	28.5		760	40	270	6
10.4	ALUMINUM.	18		680	23	250	3
13.	CADMIUM.			480	23		
14.	MAGNESIUM.			390	19	150	27
16.3	TIN.	3.4		430	34	135	35
18.1	LEAD.	2.36		190	51	84	17
9.1	PLATINUM.	35		1600	33	650	11

FIG. 8.

the absolute zero. This is also probably some function of the atomic volume, and I have found that atomic volume $\frac{4}{3}$ approximately agrees with facts. Consequently, the rigidity

[8] The law is, of course, only approximate. The fact that the atoms have so small a space in which to move is our warrant for treating them as if they were stationary.

and Young's modulus may be approximately expressed as varying inversely with the square of the atomic volumes.

The accompanying curve, *Fig. 9*, shows these relations. It will be seen that the agreement is fairly close.

The formula for the rigidity is

$$28 \times 10^{12} \,/\, (\text{atomic volume})^2.$$

That for Young's modulus is

$$78 \times 10^{12} \,/\, (\text{atomic volume})^2.$$

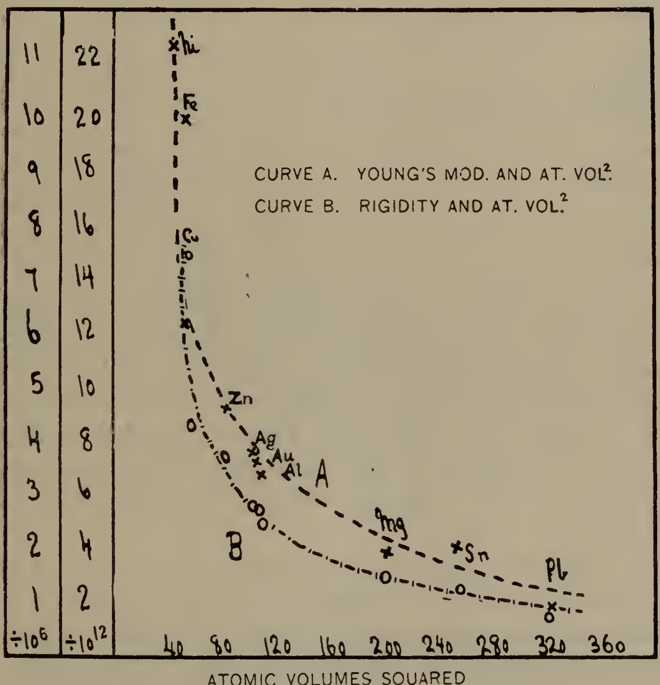

FIG. 9.

As regards the tensile strength, we see that with the two rods, in the case of the smaller atoms, each atom having the same charge, since the force varies inversely as the square of the distance, the attraction per atom will be 2^2 as great. Moreover, there will be 2^2 as many atoms. Hence, as in the case of the rigidity and Young's modulus, the tenacity will vary as the $\frac{4}{3}$ power of the atomic volume.

I find, however, that it is necessary to take into account, as before, the change with temperature. Assuming this to be proportional to the melting point in degrees measured from absolute zero, we get the following formula, which it will be seen agrees fairly well with experiment.

FOR WIRES 1 MILLIMETER IN DIAMETER.

Tensile strength in kilograms =

Absolute temperature of melting point $\div$ (1·92 $\times$ atomic volume$^{4/3}$).

Metal.	*Observed.* (*Wertheim.*)	*Calculated.*
Iron	65	74
Copper	41	48
Platinum	35	48
Silver	29·6	29
Gold	28·5	29
Aluminum	18	18
Zinc	15·7	16
Tin	3·4	5
Lead	2·36	4

By this method I calculated the tensile strength and rigidity of the metal glucinum, and found that it should probably possess very valuable properties. I had hoped to have had some fairly large specimens of this metal here to-night to show you, but the great chemical difficulties met with in preparing the pure salts have delayed matters, though I have several pounds of the fluoride nearly ready for use.

From this it will be seen that we have, at least, a plausible hypothesis, which, in the case of the metals for which the data are accessible, agrees closely with the actual tests. I take this opportunity of pointing out a fact which I did not know till some years after the publication of this theory, and which seems to have been quite overlooked.[9] This is, that a relation between rigidity and atomic volume had been previously noticed by Wertheim, though his formula is radically different from that given by me, and he did not advance any theory as to its nature, or attempt to apply it to tensile strengths.

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[9] *Annal. de Chim. Phys.*, III, **12**, 385.

The application of this theory to alloys is one of more difficulty. We see at once that, in general, the addition to a metal of large atomic volume of one whose atoms are small, must increase the tensile strength of the former. This was discovered some time ago by Roberts-Austen as an empirical fact. He proved it for the case of gold alloys. He shewed that the exceptions to the rule were caused by

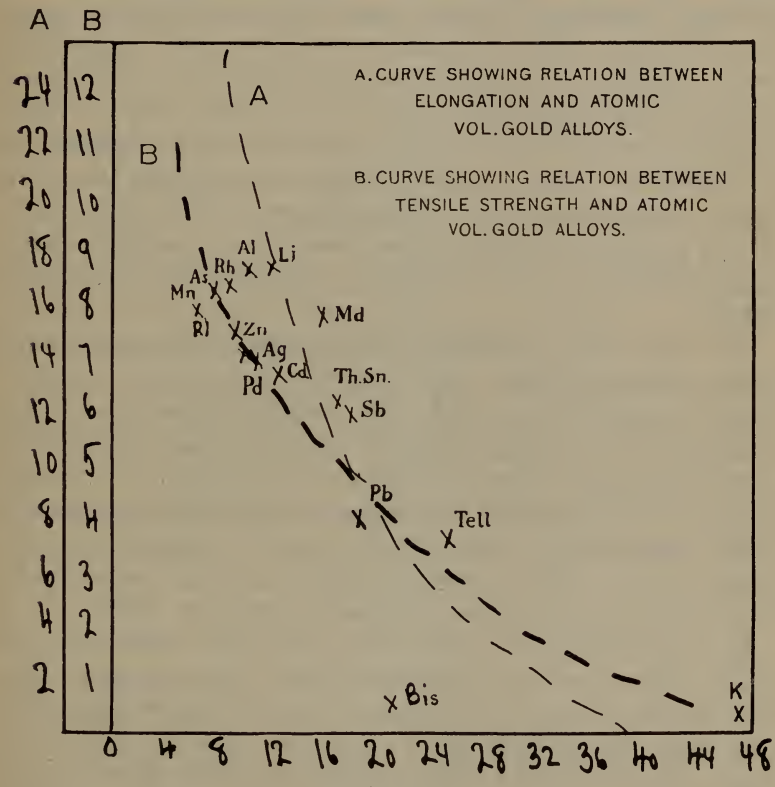

FIG. 10.

the fact that what we call chemical combination (*but which I believe to differ from cohesion only in that the resultant product of a cohesion effect is isotropic, while that of chemical action has cleavage planes; or, in other words, that the atoms in the one case are symmetrically grouped in every direction, and in the other they are only symmetrically placed about certain axes or planes*) takes place; and he was able to prove that in the case

of one exception, that of the alloy of aluminum and gold, which gives a less (*Fig. 10*) tensile strength than it should theoretically, such an alloy is actually produced.[10] Even in the case of the chemical compounds, however, I believe that the rule still holds as regards hardness, though no experiments have been made, so far as I know, on these lines; for if what I have said as to the difference between chemical and cohesion effects be true, the aluminum alloy of gold would have its theoretical tensile strength (or even a greater, since the fact of there being cleavage planes means that the atoms are not equi-related to one another, and this means abnormal contraction in volume and hence hardness), were it not for the fact that tensile strength tests give the *minimum* cohesive force and not the average. In such cases, however, we might expect measurements on the elasticity to give more concordant results.

We see from this why it is that steel is so hard and strong, first, because with copper it has the lowest atomic volume of any of the metals of the arts, and secondly, it is alloyed with that element, which, of all elements has the smallest-sized atoms, *i. e.*, carbon. The two elements work together, the carbon increasing the cohesion of the iron, and the iron destroying the tendency of the carbon to form cleavage planes. The result is the magnificent material to which our civilization owes so much.

It is interesting to compare the iron alloys with those of copper, since these two elements have approximately the same atomic volume. Even with both in a chemically pure state, the iron would have a greater strength than the copper, as the former has a higher melting point; and, consequently, when both are at the same temperature, the atoms of the iron will be closer together. Moreover, we do not know of any substance, which has so small atoms as carbon, that will alloy with copper. It is possible that an alloy of *boron* with copper would result in a material of great

[10] A curve which does more justice to Roberts-Austen's researches is contained in his book on metallurgy. By an unfortunate accident I have to present *Fig. 10* instead.

value,[11] but I am not aware that this experiment has been made. Theoretically, it is promising. So, also, an alloy of boron with aluminum might be of value.

To speak next of elasticity: It is evident that the amount to which it is possible to stretch a metal before it breaks must be very small. Exactly how much can only be ascertained by measuring the strain necessary to produce set in very fine wires. In metal bars of appreciable size, set takes place long before the average stress over the cross section has reached the amount necessary to produce set if the stress were distributed evenly, and before the bar has been lengthened more than $\frac{1}{10}$ of 1 per cent.; but piano wire may lengthen 1 per cent.

It is therefore very evident, if the theory which I have put forward be correct, that the elasticity of such a substance as india-rubber or jelly cannot be due to the same cause as that which gives elasticity to metals, *i. e.*, to the direct attraction of electrostatic charges.

Some seven or eight years ago, I was requested to discover some insulating substance that should resemble rubber in all respects, but, in addition, should be non-inflammable. I found, without much difficulty, that practically all hydrocarbons could be made non-inflammable by taking out their hydrogen atoms and substituting chlorine; but how to get them elastic was a matter which for a while troubled me. I finally found, after many experiments, that it quite often happened that, when two substances were mixed together but not dissolved, the resultant product was much more elastic than either of its components. It was then noted that all substances which are highly elastic are, as actual observation shows, made of two or more compounds in a state of mixture. In the case of rubber, for instance, we have for its components, neglecting the oxidation product (which is not found in fresh rubber), two substances: one which is somewhat like horn—hard, elastic,

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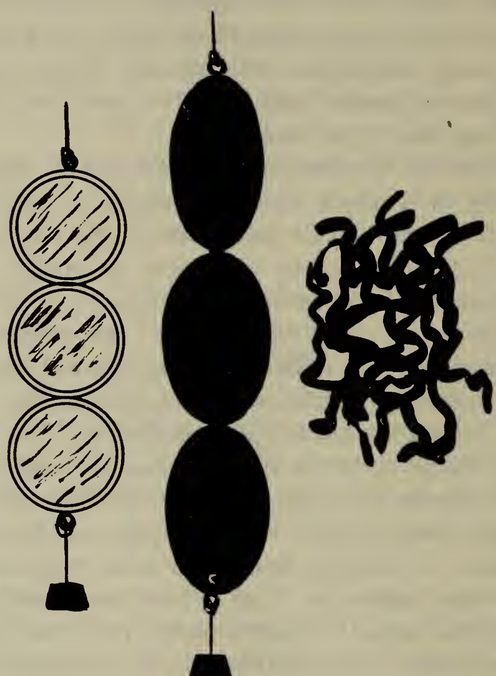
[11] M. Moissan has found, as I predicted some years ago, that the alloy of boron and iron is very hard. He has also succeeded in producing the well-known carbon boride in large quantities, and it would seem as if both these substances should have important applications.

but possessing very little extensibility; and another substance, like a very thick molasses, or a soft asphalt, or stearin pitch. Neither of the two has anything like the elasticity of india-rubber itself. The same holds good of other substances, as ivory, or soap-jelly.

How this mixing can confer such great elasticity is seen from the following considerations: Suppose we have a copper ball filled with a practically incompressible fluid, such



a *b* *c*

FIG. 11.

as water, *Fig. 11 a*. Let the radius of the sphere be 1 centimeter. Suppose I pull it out until it forms an ellipsoid, and until its major axis is 3 centimeters long, *Fig. 11 b*. Then, on the assumption that the thickness of the skin remains constant, we have an increase of area of 13 per cent., or a linear elongation of 6 per cent. But as the skin is stretched, it contracts in thickness, so that, for this reason, a less linear extension is needed, in this case only about 1·5 per cent.

Thus we get an elongation of 50 per cent., at the expense of only 1·5 per cent. of elongation of the material which does the stretching.

Now, it is fairly easy to see that a lump of the tar-like component of india-rubber, surrounded by strings of the horn-like substance, would give a similar effect; for the strings may be considered as forming the walls of the sphere, and the viscous substance as taking the place of the water, *Fig. 11 c*. Thus we may have a very great extension of an india-rubber strip, with but little actual extension of the horny substance, and none at all of the other component.

That this is the true explanation of the large elasticity in such substances is rendered probable from other considerations. The first is the fact that if we masticate the rubber too long, or treat it in any way which would destroy such a constitution as I have described, it loses its elasticity in great measure. Another convincing proof is the following: What will happen if I suddenly pull out the water-filled ball? I compress the water, and it will heat. If I leave it extended for some time, and then let it contract, it will cool. Exactly the same phenomena can be observed in the case of india-rubber by placing a rubber band between the lips and pulling it.

Again, what would happen if, whilst the ball were stretched, I heated it? Evidently the water would expand, and, in expanding, would force the ball to return to its original spherical shape. Here we have a curious paradox—contraction caused by expansion—and this phenomenon is exactly duplicated in the case of rubber.

Evidently the expansion will be asymptotic in the case of the ball. Here is a curve, *Fig. 12*, showing that the same holds for the rubber strip. The area between the up and down curves is due to hysteresis, and, as you will see, strikingly resembles the hysteresis curve of iron, as also do many curves of chemical action.

The hysteresis is caused by the fact that, whilst the strip is being stretched, it gives out heat, and, whilst contracting, absorbs it again. (In passing, I may say that this hollow, water-filled ball would seem to be capable of some practical

applications. As one, I would say that if a weight be hung to the bottom of such a ball, it would form a very sensitive thermal indicator, since it would give a much greater movement than either the water or copper would if they expanded separately. A series of balls could be used, instead of a spring, where great elasticity and little fatigue were desired, or for buffers, and would have a great advantage over rubber in that the water has a much greater capacity for heat than india-rubber.)

My reason for taking up this branch of the subject is that, having discussed metals and alloys in the isotropic

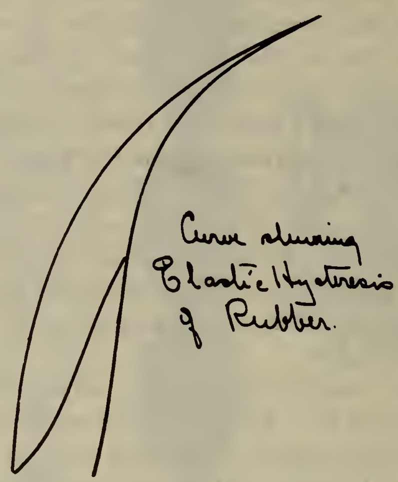


FIG. 12.

state, and in an æolotropic state produced by pressure or chemical action, the subject of metals and alloys rendered non-homogeneous by rolling, forging or other manipulations would naturally follow. We are all familiar with the fibrous structure shown by rolled and forged soft iron, and here we have, just as above, a structured substance which is thus rendered more elastic.[12] Though this is not accomplished to nearly so great a degree, I believe that the principle is the same, and having discussed it so far in the case of or-

[12] See, for instance, the cuts given by Seaton, in *The Engineer*, April 10, 1896.

ganic substances, it is unnecessary for me to say more, except this, that the mysterious failures of wrought iron may be analogous to this loss of elasticity of rubber which has long been kept under tension, as we see it in the case of rubber bands long used in holding letters. In both cases, possibly, the weakening is due to the fact that the greater part of the longitudinal strain comes on the fibrous constituent. To take a typical case, as it was reported to me, the bed-plate of a large engine was fastened down with the best wrought iron bolts screwed up tightly. After the lapse of about ten years, the bolts were removed and found so brittle that they broke when dropped on the floor. This certainly seems analogous to the case of the rubber band. Possibly the vibration may have helped matters. It would be an interesting experiment for some of our engineering laboratories to undertake, to suspend some pieces of iron stretched by weight, to, say, one-quarter of their set stress, and to test them after the lapse of a few years, during which time some of them had been constantly subjected to vibration.

The last phenomenon which I shall discuss in this lecture is elastic hysteresis, by which is meant the failure of a strained metal to return exactly to its original position.

This is most noticeable when wires are used as suspensions for mirrors, or needles in delicate apparatus. In a D'Arsonval galvonometer, for instance, if we make the suspensions of copper wire, on deflecting it and then removing the force, the coil will not return exactly to zero. This is due partly to the fact that the copper in the coil has become magnetized (as was first pointed out, I believe, by Mr. Willyoung), and partly because the wire has received a permanent set, though the twist was far within the elastic limit. We see very easily how this can happen. In the copper wire, no matter how carefully we anneal it, some of the atoms will be in positions of unstable equilibrium, for the atoms are all vibrating with great velocity, and, though these atoms have a certain *average* velocity, and as such exercise a certain average kinetic repulsion for each other, and though this repulsion does not get to be sufficient to overcome the attraction of cohesion until the body is heated

to that temperature at which it becomes a gas, yet, as this velocity is only an average, a very considerable number of the atoms have velocities differing from this mean amount.

The number and the amount of difference will be a question of probabilities; but we know so little about solids that it is impossible to calculate the result. Still, we may be fairly sure that there is always a certain number of atoms in the wire whose velocities are so high that their kinetic repulsion nearly or quite overcomes the attraction of cohesion.[13] If the wire be not strained by twisting, these atoms will not affect matters, but if the wire be twisted, then the atoms are all in a strained position, and when any atom can overcome the force of cohesion, it will move into an easier position. Consequently, when the twisting force is removed, the wire will now turn back and would come to its original position, but for the fact that these atoms, which had moved into positions where they were not strained when the wire was bent, now become strained when the wire untwists and tend to hold it back.

To this effect, when produced by longitudinal stress, may possibly be due that brittleness in wrought iron above referred to.

Another action, first pointed out by Kohlrausch, is that the wire appears to have a sort of memory. Thus, if we twist a wire clockwise, and then counter-clockwise, then clockwise again, on letting it go it first returns nearly to zero, then twists counter-clockwise, clockwise and counter-clockwise again in succession. This will readily be understood from what has been said above, if we note that the rate of creeping after the return to the false zero decreases as the wire comes nearer to the true zero. It is really the superposition of three curves.

Hysteresis is also of interest from this point of view, inasmuch as it gives us an idea how consciousness and thought may be produced by merely physical phenomena. In fact, when we consider the great complexity of the or-

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[13] *Vide*, for instance, the recent experiments of Roberts-Austen on the diffusion of metals at comparatively low temperatures.

ganic molecules which form part of our bodies, it is even possible that this is the real cause. However, it is unnecessary to speculate so far in advance of our knowledge of the subject.

But as every one is more or less interested in the study of mental phenomena, I will explain what I mean by saying that hysteresis enables us to see how purely physical causes might give rise to all the phenomena which we attribute to a something which we call mind.

I hesitated some time before I decided to present the matter in this aspect before you, because I know how severely it can be criticised. Still, the theory is now some two years old, and I have been unable to see any flaw in it. I have presented it to a number of men skilled in the science of mental phenomena, and found no objections to it which I can regard as valid. Therefore, I lay it before you, in the hope that, even if the theory as I present it be not true, it may at least lead, from the newness of the view, to results of value.

Objections may be raised. It may be said that a physicist dealing with mental phenomena is going somewhat beyond his province. I should be somewhat sensitive to such a criticism. I remember, whilst a schoolboy, reading a speech of some Greek orator, in which he hits at his rival by commenting on the jaunty way in which the latter used to preface his addresses—" O, fellow-citizens, I haven't given the matter any particular consideration; in fact, I didn't know anything about it till a few moments ago; but if you want to know exactly what to do I will tell you." I suppose I would have been caned for such a translation as that, but I have given the meaning about as I remember it; and I thought at the time it was a pretty nasty hit. Therefore, I will say that I spent—wasted, I am sometimes inclined to put it—a considerable portion of nine years in the study of metaphysical writers; consequently, what I say I do not say as one who is entirely ignorant of the subject, though I may be a little rusty in some of the jargon, which, in metaphysics, as in other pseudo-sciences, makes an important part of the subject.

Again, it may be objected that the theory is incomplete and insufficient. That I should be able, alone and in the space of a few years, to develop a complete and satisfactory theory of mental phenomena, is an idea which has not occurred to me.

I find that practically all my scientific friends with whom I have exchanged opinions agree that thought will ultimately be found to be a purely physical action. I find that the non-scientific thinker is always repelled by this idea, and speaks of the wickedness of attempting to degrade mind to the level of matter; but, in the first place, it would appear rather as the raising of matter to the level of mind; and, in the second place, we have to go on the evidence that is placed before us.

But to appreciate the general trend of evidence and to get a definite idea of how life can be a branch of physics are two different things. Many things which are observed in crystal formation are somewhat akin to the vital processes, and it has recently been shown that movements are produced by capillarity in certain mixtures of oil and water, which strikingly resemble protoplasmic motions. Yet the subject is an unusually complicated one. It took several thousand years to make quinine, but the atoms in a molecule of quinine are only a small fraction of the number in a molecule of protoplasm; and with the increasing number comes increasing unstableness, so that we need not hope to see living matter artificially produced, for, I believe, at least a hundred years, even taking into account the fact that scientific knowledge increases at a compound rate—though of course we may at any moment learn that some fortunate experimenter has, by a series of lucky chances, hit upon the solution.

Can we conceive of the thing? Some time ago, as the result of my metaphysical study, I should have said "no," since the result (about the only one) of this pseudo-science is to give one a strong mental set towards regarding mind and matter as things eternally distinct. This I now perceive to rest on the same kind of foundation as Zeno's paradox about motion.

I shall touch very briefly on the matter, though it is a most interesting one; and, during the two years I have been working at it, it seems capable of very considerable development.

Suppose that we took two manikins, and by ordinary mechanical contrivances, say with the aid of a device worked by the expansion of a heated fluid, constructed one of them so that, on bringing it up to a lighted candle, it would thrust its hand into the flame, and when the hand became heated the manikin would withdraw it, the action depending upon the elasticity of a wire spring which we may suppose to be placed in its head. So far, the toy is simply an automaton. It is influenced entirely by circumstances. Bring it to the candle a thousand times, and it will still thrust its hand in the flame.

Suppose we now unscrew the head and screw on another one in which the spring is made of a metal showing elastic hysteresis very markedly. Now, on bringing it to the candle, it will put its hand in the flame as it did before and will bring it out again; but now there is a difference. The wire has its atoms arranged differently, and so the future action of that spring will no longer be dependent merely upon its circumstances. Another factor enters in, that is, the past history of the spring; and the action of the manikin will now be due to the resultant of the two. So that by taking advantage mechanically of the hysteresis of the spring, we may, though using the same mechanism in the body part of the manikin, have two entirely separate sets of acts. So with our device. Suppose the second head is screwed on; bringing it up to the candle as mentioned before, the hand is thrust in and withdrawn. Bring it up a second time; instead of the act being repeated, the hand is now withdrawn, and no matter how many times the flame is placed near it, the hand always withdraws. If, however, the head be left alone for a few months; then, on bringing the candle near, the hand will be thrust in it again; the manikin has temporarily lost its memory, but, the impression being again renewed, it now once more avoids the flame.

Suppose, now, we have a more complex manikin, in fact, a manikin capable of acting as a man does, and arranged so that any two movements of parts of its mechanism, which took place consecutively, were thereafter always linked together, just as two consecutive twists in a hysteretic wire; then the fact that all actions would be divided into two parts, one affecting it directly and the other not, would give rise to actions which would not be differentiated from those caused by what we call consciousness. In other words, it is possible to conceive consciousness as being an acquired thing, and a necessary consequence of one's actions being determined, as in the case of the manikin, not alone by one's circumstances, but also by one's previous history.

We have gone far enough into this question for a lecture on physics; but I cannot refrain from pointing out that this offers the only rational means of escape, of which I am aware, from the old dilemma: "How can a man whose actions are determined by circumstances, heredity, etc., be held responsible for his actions?" The answer, on this theory, is very simple: "Man is himself the majority of his circumstances," and as his circumstances are responsible for his actions, he, as the majority of circumstances, must be held chiefly responsible.

I must reiterate that this is to be taken as an illustration merely of the way in which mental phenomena *may* be due to physical causes. Ability to distinguish between partial and complete parallelism is all that separates the so-called "crank" from the scientific reasoner. When we see two lines of fact lying side by side we are too apt to consider that we have happened upon a tramway to truth, and too instant to equip it with a theoretical rolling stock. If the parallel be not exact—if the rails spread—there is grief for the investigator. Hence always the very greatest need for caution.

A REVIEW OF RECENT SYNTHETIC WORK IN THE CLASS OF CARBOHYDRATES.*

BY HELEN ABBOTT MICHAEL.

Evolution is so universal, whether as exhibited in the unfolding of human conceptions, or in the making of worlds, that in all reason it may be accepted as a cosmic principle. The factors of evolution are essentially constructive and destructive ones, since growth and decay, progress and retardation, synthesis and decomposition, accompany the rhythmic pulsations of this general condition of change. Likewise, the chain of chemical causality may be conceived of as closely correlated with this presentation of evolution. The notion advanced in this consideration precludes the thought of permanence. In chemical activity the atoms are ever shifting their position in space, and this unrest is indicative of the fundamental law of advance. Howsoever stable and fixed may seem the individual links of this chain, in reality the seeming stability is a condition of variation and re-arrangement of the atoms and molecules. The molecule, that smallest portion of matter self-existing when considered as the resultant of chemical reaction, is but a state of force equilibrium between the becoming and the vanishing.

In this evening's review of recent synthetic work, in the sugar group, these constructive and destructive processes are well exemplified; also, the unfolding changes so apparent in other manifestations of universal phenomena are likewise observable in the realm of chemistry. This underlying unity and dominant principle unites all aspects of the cosmos and connects the parts into a living universe of the whole.

Evolution, when applied to chemistry, as elsewhere, com-

* A lecture delivered before the Franklin Institute, March 8, 1895.

prises the notion that the conceptions of the science advance with the unfolding of its parts.

The evolution of chemical compounds is theoretically illustrated by the building of more complex compounds from simple compounds, themselves formed from the elements, which, no doubt, in turn come from still simpler sources. The complex bodies of the same type, as, for instance, the hydrocarbons of the fatty series, show development on their own lines. Passing from the fatty hydrocarbons to those of the aromatic series is another example and indication of progress to syntheses beyond. In the laboratory these processes no doubt oftentimes are carried out by circuitous methods, as Nature's sequences in these particulars are unknown. In the natural changes that rocks, plants and animals undergo, a self-directive chemical consciousness, adequate to the needs of the respective conditions, doubtlessly obtains.

There was a time, not so long ago, when many of the chemical compounds resulting from the chain of existence were isolated from animal and plant life. The key of chemical change was looked for in the study of plants, and to these sources, from life, chemists turned for new research fields.

A little later, chemical synthesis, or the production of compounds by artificial means, had its beginning. From time to time, at longer or shorter intervals, appeared the announcement of the synthesis of some compound hitherto derived from plant or animal life. But the later years of this century, from the chemical point of view, may be regarded specially as synthetic years, ever nearing the zenith of greater attainment.

The subject of sugars early attracted the attention of chemists, not only because of the industrial aspects, but also, being one of the main divisions of the classification of compounds, the study of its varieties and composition has been untiringly pursued. The vision arose in the long past of its possible synthesis. Liebig first conceived the idea of making sugar artificially. But the synthesis of this important group of compounds defied all efforts until compara-

tively recent times. The first mixture of synthetical sugars was obtained by Butlerow,[1] by the action of lime water on oxymethylene, in the form of a syrupy liquid which he named methylenitan. In 1863, Van Deen, by the oxidation of glycerine, discovered a compound which reduced salts of copper in alkaline solution, and showed other properties indicative of a sugar, although of a simpler kind than those found in nature. The discoveries of Loew, Tollens and Fischer have brought the investigations of sugars to our own times.

The researches of Naegeli, from a botanical standpoint, led him to advance a theory that starch was the origin of sugar in plants.

A later purely chemical hypothesis of the synthesis of sugars from simple compounds in the living cell, which, in turn, yield more complicated compounds, is thought by many to be a more satisfactory theory, for it coincides with our ideas derived from other branches of scientific investigation in support of the notion that from simple integrals arise intricate structures. But it is quite probable that both processes of construction and destruction are carried on simultaneously in the plant. In the laboratory, it is possible, starting with the elements carbon, hydrogen, and oxygen, to form, from these elements, compounds which are found in vegetable life. From the simple bodies thus derived are the means ready at hand to proceed to compounds of a sugar type.

The carbon dioxide in the plant is derived from the external environment of the air and soil, or the gas is generated within the plant cells. Under the influence of sunlight, carbon dioxide and water yield formaldehyde, a compound containing the group (CHO); *i. e.*, one atom respectively of carbon, hydrogen, and oxygen, known as the aldehyde group, united to hydrogen by the residual affinity of carbon. According to Baeyer, formaldehyde is the source of the plant's sugar.

In the chlorophyll grains of the green part of the leaf, it is supposed that the formation of glucose takes place.

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[1] *Ann.*, **120**, 295.

The aldehyde group enters into the constitution, and is characteristic of many of the sugars. One of the divisions in the classification of sugars containing this group is known as the aldehyde sugars. As a comprehensive name for the class, the word *aldose* has been adopted. The other class of sugars is known as the *ketose* sugars, so called from the ketone group (CO), or carbonyl, contained in their molecules.

The ease with which formaldehyde polymerizes, under favorable conditions, qualifies this compound eminently for its function in sugar formation.

Polymerization is the amalgamating, so to speak, of two or more aldehyde groups, forming a carbon compound containing a greater number of carbon atoms.

In considering the polymers of formaldehyde, Baeyer suggested that, under the influence of the contents of the plant cells, 6 molecules of formaldehyde polymerize to form 1 molecule of glucose, $6HCHO = C_6H_{12}O_6$.

It has been claimed that formaldehyde occurs in plants, and has been found in very small quantities in plant cells; but in any great proportion it acts as a poison to the living plant, and Fischer has suggested, in consequence, that there can be no doubt that other intermediary compounds occur in the formation of sugars. Bokorny[2] has made an interesting observation on the assimilation by the green cells of algæ of a double compound of formaldehyde and sodium bisulphite. He has shown that, if plants are deprived of starch and placed in an atmosphere free from carbonic acid, they are capable of forming considerable quantities of starch under the influence of sunlight, if fed upon this compound. In the dark the conversion of formaldehyde into starch does not take place.

Loew, by treating formaldehyde with lime, obtained a sugar which he called formose. Fischer has shown that this product contains sugar compounds of the composition $C_6H_{12}O_6$, and among these, one named acrose, which stands in very close relation to natural glucose.

It may be well to state here that the term sugar includes a variety of substances. It includes fruit sugar, glucose and

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[2] *Landw. Jahrbuch.* **21**, 445.

chemically allied sugar groups, some of which contain more and some less carbon atoms than glucose. These compounds are not to be confounded with the food material derived from the sugar cane or beet root, and milk sugar. Starches and gums, though conveying little idea of sugar, are chemically to be considered as sugars.

The characteristics of these different compounds are very unlike. They vary from very soluble to insoluble compounds, and from crystalline to non-crystalline bodies. But the insoluble compounds, like starch and cellulose, may be converted into the soluble sugars by the action of heat and dilute acids, and by certain ferments, as diastase. The reaction which accompanies this conversion involves the taking up of water, and at the same time the complicated molecule splits into several simpler ones. This reaction is called hydrolosis:

$$x(C_6H_{10}O_5) + xH_2O = xC_6H_{12}O_6.$$

As will be observed, the sugar group—collectively designated as "carbohydrates"—comprehends a vast widening-out vista of compounds, from a simple compound derived directly from the elements, to complex bodies with numerous isomers.

The sugars of physiological consequence are widely spread in animals and plants, and, as carbohydrates, constitute one of the three great classes of natural organic compounds, the fats and albuminoids constituting the other two classes. Lavoisier discovered that the materials of which carbohydrates are composed were carbon, hydrogen and oxygen; but the objection to the use of the term carbohydrate, which is defined as a compound containing carbon and hydrogen and oxygen in the proportion of 2–1, is its non-universality. The sugar called rhamnose, $C_6H_{12}O_5$, may be mentioned as an exception to the definition, but for purposes of classification the name carbohydrate has been retained by writers.

The carbohydrates have been divided for convenience into three groups:

(1) Simple sugars, or monosaccharides, as grape or fruit sugars.

(2) Decomposable sugars, or polysaccharides, as cane or milk sugar and raffinose.

(3) Polysaccharides unlike sugar, as starch, cellulose and dextrine.

The polysaccharides are bodies made up from several simple sugar molecules, uniting with elimination of water. Thus, cane sugar may be converted into grape and fruit sugar by hydrolytic reaction, as shown by the equation:

$$C_{12}H_{22}O_{11} + H_2O = C_6H_{12}O_6 + C_6H_{12}O_6;$$

consequently, the simple sugars, like glucose, appear as the basis of the entire group.

In Nature, the simple sugars, or monosaccharides, are found not only as carbohydrates, but they occur also in combination with phenols as glucosides.

From the widely spread distribution of glucose, its uses as a food product, and considered chemically as the basis of more complicated carbohydrates, it deserves careful consideration.

The name hexose, which is the general name for the glucose group, as the word implies, shows that 6 carbon atoms enter into the composition of the individuals of the group. These carbon atoms are united in an open chain, each carbon atom, except one at one end of the chain, being united to a hydroxyl (OH) group. This end carbon atom is united with hydrogen and oxygen, forming an aldehyde group which is peculiar to these sugars. Glucose and sugars of its class are represented by the constitution which expresses an aldose or aldehyde sugar, $CH_2OH . (CHOH)_n . CHO$.

Fruit sugar, or ketose, is expressed by the formula:

$$CH_2OH . (CHOH)_n . CO . CH_2OH.$$

The reason for accepting this atomic arrangement to express the constitution of the glucose and fructose groups is based upon several considerations. Grape and fruit sugar, on reduction with hydrogen, yield the alcohol mannite. Galactose, which is also an aldehyde sugar, under the same conditions gives the alcohol dulcite. The 6 hydrogen

atoms of the hydroxyl groups of these alcohols are replaced by acetyl groups on treating them with acetic anhydride, so they must be considered as the hexavalent alcohols of the above sugars.

The aldehyde character of glucose and galactose is also shown by their behavior towards oxidizing agents. On partial oxidation, by chlorine or bromine water, they yield respectively gluconic and galactonic acids. By complete oxidation they both give saccharic acid.[3]

Conversely to the aldehyde sugars, fruit sugar is slowly attacked by bromine water. By the action of a more powerful oxidizing reagent it is decomposed into products containing fewer carbon atoms.

The aldehyde and ketone character of these compounds is shown by the readiness with which the sugars form hydrazone and osazone compounds. This reaction with phenylhydrazine is characteristic of all compounds containing aldehyde and ketone groups.[4]

The sugar varieties which to-day go to make up a magnificent display of synthetic skill include many isomers, depending upon the different arrangement of the atoms in space. In order to have a clear view over this field, it is important to ascertain the spacial relations or configuration of each member of the sugar groups.[5]

The latest publications by Emil Fischer on the stereomers of the sugar groups show an admirable agreement between the conflicting facts pertaining to the sugars which have poured in from isolated researches during past years, when these are considered in the light of Le Bel and Van't Hoff's

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[3] When a solution of the alcohol mannite is heated for some hours to 42° C. with nitric acid, it is oxidized to mannose; if the reaction is continued with increased heat, the oxidation is carried on to the acid formation.

[4]
$$CH_2OH(CHOH)_4CHO + C_6H_5HN_2H_2 = \begin{array}{l} CH_2OH(CHOH)_4CH \\ \qquad\qquad\qquad\quad | \\ \qquad\qquad\qquad\quad N_2HC_6H_5 + H_2O \end{array}$$

$$CH_2OH(CHOH)_3CO.CH_2OH + C_6H_5HN_2H_2 = \begin{array}{l} CH_2OH(CHOH)_3C.CH_2OH + H_2O \\ \qquad\qquad\qquad\quad | \\ \qquad\qquad\qquad\quad N_2HC_6H_5 \end{array}$$

[5] The configuration of a compound is the relative position of its atoms in space. The portion of chemistry treating on this subject is called stereochemistry.

theory. The names of these investigators are especially identified with stereo-chemistry, although others have followed in the same lines.

Among the writings of the past, the geometrical forms of matter were suggested by the Greeks, and later by Swedenborg as a possibility; but it was Pasteur, in 1860, who gave the underlying idea of grouping of atoms in space.

This theory explains the existence of two or more compounds of like chemical composition, by assuming different dispositions of the atoms entering into the compound.

The simplest hydrocarbon, methane, is conceived as being a tetrahedron with a carbon atom in its centre and one hydrogen atom joined at each of its four angles. The carbon atom of this compound is symmetrical, inasmuch as all the atoms to which it is united are of a like kind. In such a case stereomers are impossible.

But in order to have the conditions for stereosomerism, it is necessary for a compound to contain one or more atoms of asymmetrical carbon; that is, a carbon atom united by all of its four bonds to atoms or groups of atoms of different kinds.

Methane may be represented, for illustration, by a pasteboard tetrahedron model,[6] the angles being painted red to distinguish the points of carbon's union with hydrogen atoms. If this model be placed angle to angle with a second methane tetrahedron, the hydrogen atoms will coincide, and if one of the models be superimposed upon the other, the hydrogen atoms at each of the angles will touch, showing the symmetrical grouping. The symmetry of the molecule is not disturbed when two or three different kinds of atoms replace the hydrogen atoms of methane. But when all of the hydrogen atoms are replaced by different kinds of atoms, it will be found, on bringing the angles of like color of two models together and superimposing the one model upon the second model, that the angles of like colors cannot be made to coincide.

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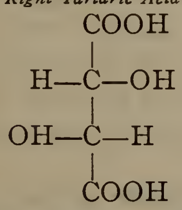
[6] The subject here and what follows was explained by means of models and charts.

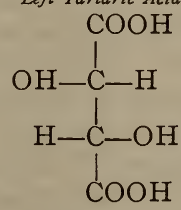
Lactic acid is an illustration of a compound containing an asymmetrical carbon. This compound, represented by the constitution, $CH_3 . CHOH . COOH$, contains two symmetrical carbon atoms, one at either end; the carbon atom which occupies the middle position is the asymmetrical carbon, since this atom is united by its four bonds with different atoms or groups. The presence of this middle carbon atom induces the conditions which cause lactic acid to appear under two *acid* modifications. By the action of these compounds on the rays of polarized light, which are turned to the right or left, depending upon the isomer, the acids are known as the right and left lactic acids. In uniting they give an inactive form.

In connection herewith, it may be well to mention the tartaric acid experiments of Pasteur. On working with certain of the salts of that form of tartaric acid, called racemic acid, he noticed that he could separate them into two crystalline forms, which in aqueous solution behaved differently towards polarized light. According to the direction that the solutions of the crystals turn the plane of polarized light, they are known as the salts of the right and left tartaric acids. The corresponding acids contain two symmetrical and two asymmetrical carbons. They may be represented in this manner:

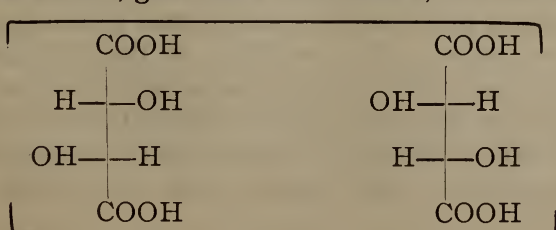
Right Tartaric Acid.



Left Tartaric Acid.



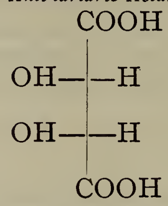
The two active modifications may be brought together, and, when united, give the inactive form, or racemic acid.



The inactive acid may be separated into its active components by chemical means, or by the action of certain ferments. These ferments have the effect of destroying either the right or the left modification.

There is another inactive form of the acid, known as the anti-tartaric acid. This is the result of synthesis, and is not decomposable into active parts.

Anti-tartaric Acid.



From what has been said it will be easy to understand the parallelism of Pasteur's classical experiments with the sugars and the application of this theory to other classes of compounds.

With the simple sugar molecules the conditions are not so complex as in the higher sugar series, and the number of stereomers is less. With an increasing number of carbon atoms the conditions of asymmetry increase and stereomers are more numerous.

In the case of glucose the number of asymmetrical carbons is four. The possible number of stereomers is sixteen, of which eleven are known. Among these, five are optical pairs. That is, each member of these optical pairs turns the plane of polarized light in an opposite direction, and one of the pair may be described as the reflected or "mirror image" of the other.

When it is remembered that glucose refers to a compound which appears under two forms in respect of its action on polarized light, the explanation, from what has gone before, of this quality is seen to rest on the space position of its atoms. The position of the hydrogen and hydroxyl groups, with respect to the asymmetrical carbons in the molecule of the active glucose which turns the plane of polarized light to the right, is diametrically opposite to the position in space of these same atoms and groups in the

The inactive acid may be separated into its active components by chemical means, or by the action of certain ferments. These ferments have the effect of destroying either the right or the left modification.

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Anti-tartaric Acid.

```
       COOH
        |
  OH—   |—H
        |
  OH—   |—H
        |
       COOH
```

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TABLE I.—Pentose, Pentonic Acid, Pentite and Trioxyglutaric Acids.

1	2	3	4	5	6	7	8
(Mirror Images.)							
COH HO—|—H HO—|—H HO—|—H CH_2OH	COH H—|—OH H—|—OH H—|—OH CH_2OH	COH H—|—OH HO—|—H H—|—OH CH_2OH	COH HO—|—H H—|—OH HO—|—H CH_2OH	COH H—|—OH HO—|—H HO—|—H CH_2OH	COH H—|—OH H—|—OH HO—|—H CH_2OH	COH HO—|—H H—|—OH H—|—OH CH_2OH	COH HO—|—H HO—|—H H—|—OH CH_2OH
l—Ribose. *l*—Ribonic acid.		*l*—Xylose. *l*—Xylonic acid.		*l*—Arabinose. *l*—Arabonic acid.		*d*—Arabinose.	

9	10	11	12
COOH H—|—OH H—|—OH H—|—OH COOH	COOH H—|—OH HO—|—H H—|—OH COOH	COOH H—|—OH HO—|—H HO—|—H COOH	COOH HO—|—H H—|—OH H—|—OH COOH
Ribo-trioxyglutaric acid. Adonite (inactive).	Xylo-trioxyglutaric acid. Xylite (inactive).	*l*—Trioxyglutaric acid. *l*—Arabite.	

Hexose, Hexonic Acids, Hexite and Saccharic Acids.—*a.* Mannite Group.

13	14	15	16	17	18	19	20
COH H—|—OH H—|—OH HO—|—H HO—|—H CH_2OH	COH HO—|—H HO—|—H H—|—OH H—|—OH CH_2OH	COH HO—|—H H—|—OH HO—|—H H—|—OH CH_2OH	COH H—|—OH HO—|—H H—|—OH HO—|—H CH_2OH	COH HO—|—H H—|—OH HO—|—H HO—|—H CH_2OH	COH H—|—OH H—|—OH HO—|—H H—|—OH CH_2OH	COH H—|—OH HO—|—H H—|—OH H—|—OH CH_2OH	COH HO—|—H HO—|—H H—|—OH HO—|—H CH_2OH
l—Mannose. *l*—Mannic acid.	*d*—Mannose. *d*—Mannic acid.	*l*—Idose. *l*—Idonic acid.	*d*—Idose. *d*—Idonic acid.	*l*—Glucose. *l*—Gluconic acid.	*l*—Gulose. *l*—Gulonic acid.	*d*—Glucose. *d*—Gluconic acid.	*d*—Gulose. *d*—Gulonic acid.

The configurations of the acids correspouding to the above have been omitted.

b. Dulcite Group.

27	28	29	30	31	32	33	34
COH HO—|—H H—|—OH H—|—OH HO—|—H CH_2OH	COH H—|—OH HO—|—H HO—|—H H—|—OH CH_2OH	COH HO—|—H HO—|—H HO—|—H HO—|—H CH_2OH	COH H—|—OH H—|—OH H—|—OH H—|—OH CH_2OH	COH H—|—OH H—|—OH H—|—OH HO—|—H CH_2OH	COH H—|—OH HO—|—H HO—|—H HO—|—H CH_2OH	COH HO—|—H H—|—OH H—|—OH H—|—OH CH_2OH	COH HO—|—H HO—|—H HO—|—H H—|—OH CH_2OH
l—Galactose. *l*—Galactonic acid.	*d*—Galactose. *d*—Galactonic acid.						*d*—Talose. *d*—Talonic acid.

other modification of glucose which turns the plane of polarized light to the left.[7]

The right glucose may be spoken of as the "mirror image" of the left one, for by no possible turning can the configuration of the one be superimposed upon the other. Thus they are called enantiomorphic; but united, they give the modification inactive towards polarized light. The inactive glucose may be again decomposed into the two active forms.

The question naturally arises: Why are these configurations represented as they are on the diagram?[8] It would carry us beyond the time allotted for this occasion to go into the reasonings for each case. I will only take one or two examples. But it may be stated generally that the observations made on these sugars from experimental facts are in accord with theory.

On the chart, beginning at the top of the diagram, are the two *triose* sugars, each with one asymmetrical carbon. On the next lines are the four *tetroses*, which have been made synthetically. There are eight *pentose* sugars having three asymmetrical carbons; and below these are represented the sixteen *hexose* sugars, to which glucose belongs. I have not considered it necessary to continue the representation of the higher sugars on the chart.

But, suppose that I should change the aldehyde group of these sugars into a corresponding alcohol group, it would become apparent that the conditions for asymmetry were changed. Each of the end carbon atoms, in its atomic relations, is alike, and these alcohols contain only two asymmetrical carbons. The configurations for the pentose sugars, one and two, here given, are unlike. They are the mirror images of each other. When reduced, however, to their alcohols, the identity of the alcohols arising from these two sugars becomes apparent on turning the end group of one of the compounds in the plane of the diagram, and bringing this group to the top of the other configurations. Also, if these alcohols are imagined to be the acids of the group, the tri-oxyglutaric acids, the (COOH)

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[7] This was represented on a diagram.

[8] See Table I.

groups standing at each end of the carbon chain when the acid is turned in the same plane on the diagram as the alcohols, it will be seen that one acid configuration results from two sugar ones, as in the former case of the alcohols.

There are only four alcohol and acid isomers for the eight sugar isomers in this group. In the other higher sugar groups, the conditions are somewhat changed. But by studying the results of oxidation or reduction on sugars, it may be shown that the compounds so obtained point to the probable configuration of a given sugar; and in this way, these formula express the conclusions of actual experiment.

These active asymmetrical compounds are obtained directly from natural products, or are derived from optically active compounds. If compounds are formed from inactive ones, and inactive modifications arise, these inactive forms must be decomposed in order that the active form may appear.

Although these active compounds are the resultants of accompanying life processes, they are not regarded by the chemical thinkers of the day as essentially due to a life force. Fischer believes that these active compounds will all be made synthetically. This is by no means assuming that the knowledge to fabricate these active substances will give into the hands of the chemist the secret touch to set these molecules into a life mechanism.

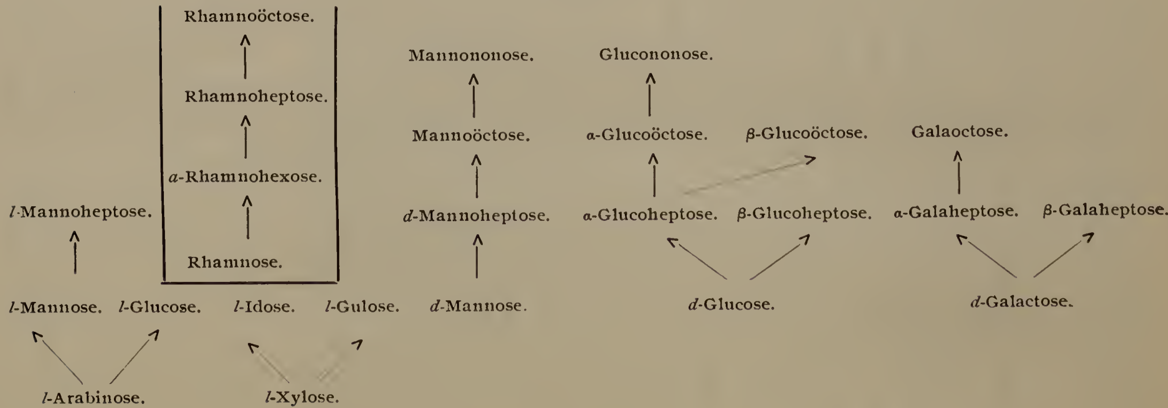
The example of the glorious period of the highest achievements in Greek art remains as a reminder that neither the skill of a Phidias nor a Praxiteles could give to their creations the breath of life. The analagous height and limit of relative perfection in attainment is seen in other developments of human conception. Each later development may reach a higher round of the ladder than its predecessors, and the standpoint of vision may be a line nearer that goal which seems to recede as the effort of advance reaches forward.

An Arabian alchemist, it is said, first obtained grape sugar, or glucose, in a solid form, by concentrating grape sap. It was obtained pure by the chemist Marggraf, in the middle of the last century. The conversion of starch into grape sugar by boiling with dilute acids was discovered by

TABLE II.

	Aldose.	Mono-basic Acids.	Di-basic Acids.	Polyvalent Alcohol.
Biose	Glycolaldehyde.	Glycolic acid.	Oxalic acid.	Glycol.
Triose	Glycerose. (*Mixture of aldose and ketose.*)	*d-i*—Glyceric acid.	Tartronic acid.	Glycerine.
Tetrose	Erythrose.	Erythritic acid.	4 Tartaric acids.	2 Erythrite.
Pentose	*d-l-i*—Arabinose. Xylose. *l*—Ribose.	*l*—Arabic acid. Xylonic acid. *l*—Ribonic acid.	*l*—Trioxyglutaric acid. Xylo-trioxyglutaric acid (inactive). Ribo-trioxyglutaric acid (inactive).	*l*—Arabite. Xylite (*inactive*). Adonite (*inactive*).
Methyl Pentose	Rhamnose. Chinovose. Fucose.	Rhamnic acid.		Rhamnite.
Hexose — Mannite Group	*d-l-i*—Glucose. *d-l-i*—Gulose. *d-l-i*—Mannose. *d-l-i*—Idose.	*d-l-i*—Gluconic acid. *d-l-i*—Gulonic acid. *d-l-i*—Mannic acid. *d-l-i*—Idonic acid.	*d-l-i*—Saccharic acid. *d-l-i*—Manno-saccharic acid. *d-l-i*—Ido-saccharic acid.	*d-l*—Sarbite. *d-l-i*—Mannite. *d-l*—Idite (1).
Hexose — Dulcite Group	*d-l-i*—Galactose. *d*—Talose.	*d-l-i*—Galactonic acid. *d*—Talonic acid.	Mucic acid (inactive). *d-l*—Talo-mucid acid. Allo-mucic acid.	Dulcite (inactive). *d-i*—Talite.
Methyl-hexose	α—Rhamno-hexose.	α—Rhamno-hexonic acid. β—Rhamno-hexonic acid.		α—Rhamnohexite.
Heptose	*d-l-i*—Manno-heptose. α—Gluco-heptose. β—Gluco heptose. α—Gala-heptose. β—Gala-heptose.	*d-l-i*—Manno-heptonic acid. α—Gluco-heptonic acid. β—Gluco-heptonic acid. α—Gala-heptonic acid. β—Gala-heptonic acid.	*d*—Manno-heptanpentoldic acid. α—Gluco-heptanpentoldic acid (inactive). β—Gluco-heptanpentoldic acid. α—Gala-heptanpentoldic acid. β—Gala-heptanpentoldic acid.	*d-l-i*—Mannoheptite (Perseit). α—Glucoheptite (inactive). α—Galaheptite.
Methyl-heptose	Rhamno-heptose.	Rhamno-heptonic acid.		
Octose	Manno-octose. α—Gluco-octose. Gala-octose.	Manno-octonic acid. α—Gluco-octonic acid. β—Gluco-octonic acid. Gala-octonic acid.		Manno-oclite. α—Gluco-octite.
Nonose	Manno-nonose. Gluco-nonose.	Manno-nononic acid. Gluco-nononic acid.		Gluco-nonite.
Aromatic Series	Phenyltetrose.	Phenyltetronic acid.		(1) Ber. 28, 1975.
	Ketose.	**Structure Unknown.**	**Aldehyde Acids.**	
Triose	Dioxyacetone (contained in glycerose).		$(CHOH)_4<^{COOH}_{COH}$	Glucuronic acid. Oxygluconic acid.
Hexose	*d-l-i*—Fructose. Sorbose.	Formose. β—Acrose.	$(CHOH)_5<^{COOH}_{COH}$	Aldehydgalactonic acid.

TABLE III.


Rhamnoöctose.
Rhamnoheptose.
a-Rhamnohexose.
Rhamnose.
l-Mannoheptose.
l-Mannose.
l-Glucose.
l-Idose.
l-Gulose.
l-Arabinose.
l-Xylose.
Mannononose.
Mannoöctose.
d-Mannoheptose.
d-Mannose.
Glucononose.
α-Glucoöctose.
β-Glucoöctose.
α-Glucoheptose.
β-Glucoheptose.
d-Glucose.
Galaoctose.
α-Galaheptose.
β-Galaheptose.
d-Galactose.

Kirchhoff, in 1811. No less interesting is the recent work of Rohmann, wherein he shows that blood serum converts potato starch into dextro-glucose, and that finally, at the end of the reaction, maltose, likewise soluble starch and dextrine, remain.

From all sources the number of simple sugars, from the beginning of the century to less than ten years ago, numbered not over 6. Now, by means of synthetical research, not less than 30 simple sugars are known, and 7 of them are natural products. Among the 7 carbon atom sugars, by calculating the possible number of isomers, 32 are possible, of which only 6 have thus far been obtained. Of the 128 possible nonnose sugars, as yet but 2 have been made.[9]

To carry out the thought of the sugar group development it will be necessary to give rapidly an outline of these sugars before summing up the methods which led to their synthesis.

Under the mannite group are included grape sugar, and sugars possessing the same chemical composition as grape sugar. The mannose sugars also come under this group, with their corresponding alcohols and acids. The right, left and inactive mannose correspond to the *d-l* and *i* glucose. The right mannose is formed at the same time as the right fructose, by the careful oxidation of the alcohol mannite. It was first obtained in this way. It may be mentioned that mannite is found in manna. Mannose may also be obtained from the natural carbohydrates by hydrolytic reaction. It is also found in the fruit of many palms. A very cheap source of supply is from the shavings of vegetable ivory in the manufacture of buttons. In separating the right mannose from its solutions, its phenylhydrazone compound is used. This compound is very insoluble, and affords a characteristic test for this substance.

The left mannose is obtained from the left arabinose. The arabinose compounds contain 5 atoms of carbon.[10] The cyanhydrine reaction in the sugar series, or Kiliani's reaction, is the one employed in its formation. This

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[9] The table shows the present sugar status.

[10] By right, left and inactive acids, of course, is meant the effect of these compounds on polarized light.

method has opened the field to some of the most important discoveries in sugar synthesis. In this reaction prussic acid unites directly with sugar,[11] and in this way the number of carbon atoms in the sugar chain may be increased and a higher synthetic compound formed. Upon the addition of prussic acid to sugar compounds, the further processes of saponification and reduction are necessary before obtaining a higher sugar. By this method it is possible to pass from sugars containing a few carbon atoms to sugars representing a higher synthetical series. However, this method can only be used with sugar compounds containing not less than 3 carbon atoms. Such compounds have the power of forming lactones, and sugars of a higher carbon percentage are obtained by reducing these lactones.[12] It is by the use of this method that Fischer has obtained some of his most brilliant achievements.

The right, left and inactive glucose and idose, which are stereomers of glucose, have been obtained synthetically from their corresponding acids. Idose is named from the symmetrical form of its molecule, and is among the latest discovered compounds of this group. The acids of these last two sugars are isomeric with the sugar acids obtained by oxidizing glucose and mannose.

Two other sugars, which may be mentioned as belonging to the hexoses, are galactose and talose. The right, left, and inactive galactose have been obtained. The *d*-galactose as well as the *d*-glucose may be derived from milk sugar by hydrolysis. The latter may also be obtained by the same means from other carbohydrates. Galactose yields, on reduction, an alcohol called dulcite. These

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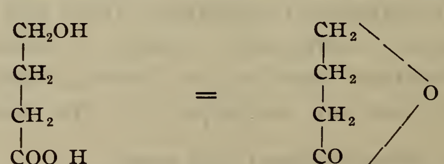
[11] $C_2HOH(CHOH)_4CHO + HCN = CH_2OH(CHOH)_4CHOH.CN + H_2O$.

[12] The lactones are gamma hydroxy compounds, which, by the loss of water, give an anhydride.



Counting from the one above the bottom group, the carbons are known as the alpha, beta, gamma, delta carbons, etc.

sugars belong to the second division of the hexose group, known as the dulcite group, and by oxidation yield mucic acid; whereas the sugars of the mannite division yield, on oxidation, saccharic acid. All these sugars may be separated from their solutions, in a solid form, by means of their hydrazones and osazones.[13] However, with the exception of mannose, the hydrazones of other sugars are mostly soluble in water. Hence, the reaction with phenylhydrazine is carried on to a further state, which results in the formation of the insoluble osazones. These compounds differ decidedly in color and system of crystallization. They have sharp melting points, which lead to their easy identification.

Another class of substances, which are called mercaptales, are compounds of sugar with sulphur, of the composition, $CH_2OH(CHOH)_4CH(S_2C_5H)_2$, furnishes a means of separating and distinguishing the aldehyde sugar compounds.

The synthetical sugars containing 7, 8 and 9 carbon atoms, derived from the groups containing less carbon atoms, may be made by Kiliani's method.

It is an interesting fact that the sugars containing 3, 6 and 9 atoms of carbon are fermentable; while those containing 4, 5 and 7 atoms of carbon cannot be fermented.

Fischer has suggested wherein the interest of these massive sugar molecules lies. It is in physiological research. He has proposed, as worthy of attention, that these higher synthetical sugars be experimented with as to their full physiological value. Possibly the tissues of animals nourished with these higher sugars may yield other chemical products; the liver may give a new glycogen, and a new acid may be found in the milk secretions from the mammary glands. Here may possibly be opened a new research ground for the biologist.

The pentosanes are compounds belonging to the sugars containing 5 carbon atoms. These pentosanes occur in various parts of plants of different age and development. The amount increases during the development of the plants. The wood of dicotyledonous plants is richer in pentosanes

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[13] The reaction and products of some of these sugars were demonstrated.

than those of the *Coniferæ.* It is thought by de Chalmot that these substances are reserve materials. But they seem of importance in the formation of wood, for they are developed at *this* stage.

Arabinose is one of the important members of the pentose series. It was discovered by Scheibler on boiling the gum of the cherry tree with sulphuric acid. This compound was considered by him an isomer of grape sugar; but it was shown by Kiliani to possess the formula $C_5H_{10}O_5$. Although the natural arabinose turns the plane of polarized light to the right, on account of its relation to *l*-glucose, it should be considered as a left compound. Artificially, the right turning arabinose may be made from glucose by a *building-down* process, as it were, discovered by Wohl. This process consists in passing from a sugar richer in carbon atoms to one containing fewer carbon atoms.

On boiling bran, wood, jute, straw and like substances, with acids, pentosan compounds are obtained. In some cases they may be isolated, or their presence may be proved by the furfurol reaction. This is a well-known test for their identification. If compounds belonging to the hexose groups be heated with acid, they yield lævulinic acid ($CH_3COCH_2CH_2CO_2H$). On the contrary, pentose compounds, by distillation with strong acids, yield furfurol compounds, which easily pass over with steam.

The portions of the coffee berry insoluble in water, when distilled with dilute hydrochloric acid, yield furfurol aldehyde, which demonstrates the presence in the coffee of a compound belonging to the pentosanes.

By warming with phloroglucin and hydrochloric acid, the pentosanes, as also all compounds which, by decomposition, yield sugar compounds containing 5 carbon atoms, give a cherry-red color reaction.

Ribose, a colorless syrup, and xylose, wood sugar, are isomeric with arabinose.

Rhamnose, formerly erroneously called "isodulcite," is a methylpentose. It is obtained from datiscin by hydrolytic reaction, and by the same method from different glucosides.

Fucose, obtained from the sea-tangle or grass mack, is

isomeric with rhamnose, also chinovose, which is derived from chinovite. The alcohols, xylite and adonite, belonging to the sugars xylose and ribose, correspond to arabite, the alcohol of the sugar arabinose, and are inactive.

The remaining series of compounds, which chemically belong to the same class as the sugars, are designated as biose, triose and tetrose sugars. These compounds contain, respectively, as their names indicate, 2, 3 and 4 carbon atoms. The latest addition to this list is the number containing the fewest number of carbon atoms. This is a compound with two atoms of carbon, chemically known as glycol aldehyde, and may be obtained from brom-acetaldehyde, by means of barium hydrate in the cold. This compound possesses all the properties to be expected from a simple sugar. Of these, the property of being converted by phenylhydrazine into the gloxalosazone may be mentioned. It has not been possible to obtain the glycolaldehyde *from admixture* with the brom-aldehyde from which it is derived; consequently, the behavior of this simple sugar with ferments has not been proven. Since brom-compounds act as a poison towards yeast, the mixture will probably be found not to ferment.

Triose or glycerose is considered to be a mixture of glycerin aldehyde (CHOH . CHOH . CHO) and dioxyacetone (CHOH . CO . CHOH). This compound is a syrup, and reduces Fehling's solution, and actively ferments with yeast.

The chemical sugar next higher in the scale is the tetrose sugar, which is formed by the oxidation of erythrit, and is named therefrom erythrose. This is likewise a mixture of aldehyde and ketone compounds. The regeneration of this sugar from its osazone has not yet been accomplished. The synthetical tetrose probably arises by a kind of aldol condensation. It has been isolated in form of its osazone only, which is identical with the erythrosazone.

It may be mentioned in reference to aldol condensation, that it is of two kinds. The condensation may be accompanied either by the loss of a molecule of water or by no loss of water. The former is known as aldehyde condensation, when, for example, two molecules of ethylaldehyde

are heated with zinc chloride, and a molecule of water is lost. In the latter case, the aldehyde must stand for a longer time with dilute hydrochloric acid; thence arises a condensation product known as aldol condensation.

The distinctions between the sugars characterized as the aldose and ketose sugars disappear when these sugars are converted into the osazones; for each sugar gives identically the same osazone, and this compound affords a means of passing from a sugar of one class to a sugar of the other class.

The other division of natural sugars, or the ketone sugars, of which fructose is the type, includes, up to the present time, three representatives only. Of these three sugars, only the dextra-fructose combines with prussic acid; consequently, the synthesis in this division by Kiliani's method is limited. It has not gone beyond the fructo-heptose, or a ketone sugar containing 7 atoms of carbon.

Fructose is the fruit sugar to which the sweetness of fruits is chiefly due. This sugar crystallizes from alcohol in crystals belonging to the rhombic system, whilst the crystals of glucose are obtained as fine needles. Fructose occurs in three modifications. The inactive modification is of historical interest, since it was the first synthetic sugar made out of materials obtained by synthetical means.

Of the methods which serve for the direct synthesis of sugar may be mentioned: (1) the polymerizing of formyl-aldehyde by bases; (2) a valuable synthetical means is, likewise, the reaction which corresponds to aldol condensation; and (3) Kiliani's method has been of untold value in this field; (4) the artificially made sugars may be separated from solution in form of their osazone compounds, and, in most cases, the sugars can be regenerated from these compounds.

In all cases a mixture of these osazones arise. The inactive phenyl-glucosazone is the direct source of the inactive fructose; for, by reducing the osone derived from the osazone, a ketose arises which agrees in all respects with the inactive form of fructose. It possesses all the properties of the natural fruit sugar.

By the reduction of this inactive fructose, obtained synthe-

tically, arises the inactive mannite. The synthesis of the active glucose and fructose (the natural sugars) may be made from the inactive mannite in the following way: By treating the inactive mannite with the suitable oxidizing agent, it will be oxidized to the inactive mannose and the inactive mannonic acid; the inactive mannonic acid can be split into its active constituents, the right and the left acids. The right mannonic acid yields, by reduction, the right mannose on the one hand, while on the other, by heating with chinolin or pyridin, a molecular change takes place, and the *d*-gluconic acid is obtained, which yields the active glucose. Finally, the active glucose and mannose, through their phenyl-glucosazones, may be converted into the active fructose. Thus the problem of the synthesis of the most important natural sugars has been accomplished.

Sugar, as a class, is thus derived not only from sources pertaining to the land and sea, but also, from the brief sketch just drawn, from no less a source than man's intelligence.

According to the earliest records, the sugar cane, the main source of the supply of saccharose or cane sugar, was cultivated in India for food supply. The beet sugar industry dates from our own time.

Cane sugar is found in many plant species, and occurs in grain during germination at the expense of starch, as it was observed in the barley. Cane sugar has not yet been made synthetically. It stands as one of the atomic peaks still to be scaled.

The discovery, by Biot, of the power of cane-sugar solutions to turn the plane of polarized light led Dubrunfaut, in 1847, on decomposing cane sugar, to discover fructose, the second sugar constituent of cane sugar. In the same way, we may read any day the announcement of the discovery of a chemical spy-glass, which will reveal the pathway to the synthesis of this member of the chemical chain.

Maltose, a sugar of the same composition as cane sugar, was discovered by Dubrunfaut. Maltose, a polysaccharide, has been made synthetically.

Milk sugar, which also belongs to this same division, was separated from milk as early as the year 1619, by

Bartoletti, of Bologna. Demole claims to have made it synthetically.

Starches, gums, cellulose and mucous compounds are of great physiological interest in their bearing to plant life, and the recent thorough investigations of the sugar groups will not be unavailing to bring forward a clearer knowledge of these bodies. There are many sources of starch, and some peculiarities between the different kinds. Lichenin, from Iceland moss, and inulin, from many composital plants, act the *rôle* of starch in the plants wherein they occur.

A brief reference may be given here to compounds like dextrine and lævulin, which stand intermediary between the starches and sugars. Dextrine is formed from starch by treating with dilute acids, or by diastase. According to the conditions, several dextrine kinds may be separated. A crystalline form, produced by the action of dilute mineral acids on starch for months, has been isolated. Dextrine gives with iodine a red coloration.

Glucosides are compounds of grape sugar or glucose with another substance, and naturally find place in a study of carbohydrates. Grape sugar, on account of its containing an aldehyde group, is capable of uniting with different kinds of chemical bodies to form these compounds. The compound which results on decomposing a glucoside is frequently of a complex nature. Glucosides are very widely spread in nature. In many cases the chemical constitution of glucosides is well known, and some of these compounds have been made synthetically.

Recently, Fischer has described a method of obtaining glucosides synthetically. By the action of hydrochloric acid on sugars, alcohols, oxyacids and phenols, he obtained condensation products of the nature of glucosides. These compounds, like other glucosides, do not react with Fehling's solution or with phenyl-hydrazine. But they are decomposed by acids.[14]

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[14] Also ketones, by warming and treating with hydrochloric acid, are changed into glucosides. Ketones combine with sugar; rhamnose with one molecule; arabinose, fructose and glucose unite with two molecules of acetone; sarbose, with a ketosane, yields a beautiful crystalline compound. By

These simple compounds are analogous to the more complex ones, and are of interest for their bearing on the natural glucosides. There is no essential difference between the simple synthetical glucosides and the more complicated carbohydrates like cane sugar. Indeed, the latter should be considered as the glucosides of sugar.

The list of natural glucosides is a long one. A summary of their particular occurrence and properties is unnecessary here. But a glucoside, for example, like either saponin or phloridzine, illustrates the fact that compounds of a like composition are found in closely related botanical families. Plants in which saponin occurs are nearly related in regard to their stage of evolution, and so with phloridzine-containing plants. Phloridzine, when isolated from the bark of the apple, cherry or plum tree, or from other plants belonging to the order *Pomaceæ*, is a crystalline substance of a white color when quite pure. Like all glucosides, it is decomposed by dilute acid into glucose and a second product. In this case the second product is phloretin.

From experiments on animals, phloridzine, when taken into the body, produces a condition which results in diabetes. The amount of sugar excreted from the system after ingestion is far in excess of what could be produced from the glycogen of the liver, nor would the amount of glucose in the glucoside explain the large quantity of sugar excreted. But, in fact, according to Cremer, the phloridzine passes through the system unchanged, and the sugar which arises is from the proteids of the body.

The very latest trend of investigation is to show that the

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employing a very weak solution to work with, in contradistinction to the former work with strong hydrochloric acid, α- and β-stereomers were obtained, also a third product, an acetal compound, analogous to the glucose mercaptans. In the beginning these are in excess, then they go over into glucosides.

The ketose sugars react with alcohol, in presence of HCl, more quickly than aldosans.

Fischer has also discovered, as a between-product, glucose-acetone, which is separated in fine, colorless needles. This compound is distinguishable from the glucose di-acetone.

A new glucoside, similar to amygdalin, but of a simpler formula, named amygdonitril glucoside, has been recently described by Fischer.

configuration of a compound has its place in the explanation of the functions of an organism. Also, the reasons for the fermentation of certain compounds are to be found in stereo-chemical considerations.

It is stated in a recent publication that the most ordinary functions of a living being depend more upon the molecular geometry than upon the composition of the food material. It is well known that the fermentation processes are brought about by minute organisms, and it is supposed that the geometrical configuration of the ferment coincides with that of the compound which it attacks. The most important chemical agents of the living cell are the optically active ones of the albuminoids, and these possess, consequently, an asymmetrically constructed molecule. Since the simple albuminoids result from the sugars, the fact is given in proof of the same geometrical structure for these two classes of bodies. On this reasoning it has been claimed that, when sugar comes into contact with the albumen of the yeast cells, fermentation only takes place if the geometrical form of the sugar molecule does not differ too widely from that of the yeast substance.

In some recent experiments, Fischer found that the ferments invertin and emulsin attack only the glucosides of grape sugar, whilst they leave those of other sugars—likewise starch, salicin, phloridzin and other synthetical phenol-glucosides—unacted on.

However, the α-methyl glucoside is decomposed by invertin and not by emulsin; but with the methyl glucoside the reverse occurs. These facts are given to show that a different molecule structure alters the condition.

The influence of the bacilli on chemical changes in the body is recognized. That these changes do occur is evident. Many experiments on plant tissues show this. The transformation of starch into sugar by the *Bacillus anthracis* has been shown lately by cultivating the bacillus on a potato. After a short time, the surface of the potato gave, not the blue color of starch with iodine, but the red color of dextrin. Portions of the potato were then placed in sterilized water, and, after some days, on testing the liquid, it reduced

Fehling's solution. The explanation of these changes is supposed to rest on the configuration of the molecule.

From the survey of the chart, on which are summarized the synthesis and work on the sugars, the attention of the least interested observer will be called to this fact—that a vast amount of work has been accomplished in this field, and the harmony in these groups between facts and theories is significant. That chemical compounds are *solids* and occupy space is not to be gainsaid, but there must be an adjustment between scientific facts and hypotheses. To pervert or carelessly to observe facts in order to make them, at all hazards, fit into theoretical moulds, is the highest act of treason of which the scientist can be guilty. Chemistry, studied from a geometrical basis, is of comparatively recent date. It is purely arbitrary to settle upon any particular figure to express the grouping of the atoms in space. However, the tetrahedron is the simplest expression that explains the fact.

The entire subject of the chemistry of sugars would be the chaos it was before, without the aid of geometrical speculations. These at once bring order and system to a confusion of facts.

Hegel names time and space the accidents of true existence. In the consideration of the space relations of these compounds a step is taken to the reality which lies beyond time and space and the imperfection of knowledge. These configurations represent crudely the ideal basis of what is called matter.

The next query that will occur to those who are not daily working in scientific matters is this: Is the subject of sugars, just reviewed, settled for all times? In science there is no fixed ground. The true object of scientific research is to seek truth regardless of the consequences, and on our plane, truth is evolving. To embrace, when found, that truth which seems the more evolved, even though the pet hypotheses and results of a lifetime's personal effort are laid aside, is the true aim of endeavor. This is the true scientific spirit. The magnetic needle oscillates until it finds its resting place pointing northward, and the chemist, too,

should oscillate within the arc of his science until he finds the currents flowing towards light and higher truth.

It has been said that "every man who would do anything well must come to it from a higher plane. A philosopher must be more than a philosopher." Plato was clothed with the powers of the poet, though he chose to use his poetic powers to an ulterior purpose. In the love for facts, the other side of the subject, the "mirror image," so to speak, must not be forgotten. It is from the employment of the imagination and the cultivation of the higher reasoning faculties that the true insight will come. This insight will reveal the meaning of all these phenomena, and the oneness underlying all things will become apparent. To cleanse the eye from seeing only the grosser phenomena, and to gain the perfect faultless eye of wisdom, compensated Kunala, the king's son, for the loss of his eye, which, by a cruel order, was torn from its socket.

The more apparent phenomena of a science have their true place when studied in harmony with the bold outlines of the universe. Call these outlines philosophical principles, cosmic laws, or what you will, but the facts of science, culled from many fields, only confirm the words of long ago: "Our whole existence depends on our thought; thought is its noblest factor; in thought its state consists."

Chemical facts, or the facts of any science when regarded, not as the end of endeavor, but as the means to an end, take their true place in the intellectual universe.

The facts of a science being more or less relative, in the search of truth these relative facts are useful, inasmuch as they indicate the principle which underlie the manifestations.

The ceaseless change and interchange; the impermanence of all things in Nature, whether pertaining to the so-called inorganic or organic life phenomena, is expressed by the mutations and transformations of chemical reaction.

The recurrent properties and the chemical laws, exhibited in all syntheses, as well as in breaking down processes of compounds, are in unison with the rhythmic system of evolution from which nothing in this universe can escape.

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HEAT-WASTES IN STEAM-ENGINE CYLINDERS.*
(ABSTRACT.)

BY ROBERT H. THURSTON.

INTRODUCTION.

The paper, of which the following is an abstract, was read before the British Institution of Naval Architects, at its thirty-sixth session, 1895, and is printed *in extenso* in the *Transactions* of that association, presently to be published. It is intended to give a condensed statement of the condition of the theory of the heat wastes in the steam-engine cylinder, and especially of the method of so-called cylinder condensation, which constitutes the most important of the controllable wastes of the heat-engines. As a statement of the state of the art and of the theory to date, this paper necessarily contains no important original matter, and all its essential facts have been at one or another time pub-

* *Transactions*, Institution Naval Architects, 1895.

lished, and in large proportion in the *Journal of the Franklin Institute* and in the *Transactions* of the American Society of Mechanical Engineers; but this has been thought an appropriate time for their collection and formal arrangement, with a view to exhibiting the status which has been reached at the present time.

Before taking up the paper in question, it may be well to review briefly the earlier history of the study of heat-wastes in the heat-engines. This had been done by the author of the paper, in a contribution to the *Transactions* of the British Association for Advancement of Science, at the Montreal Meeting of 1884, and the outline then given will serve, perhaps, as a satisfactory introduction to the later discussion.*

"A complete history of the development of the theory of the steam-engine would include: (1) the history of the mechanical theory of heat; (2) the history of the science of thermodynamics, which has been the outgrowth of that theory; (3) the history of the application of the science of heat-transformation to the case of the steam-engine; and (4) an account of the completion of the theory of the steam- and other heat-engines by the introduction of the theory of losses by the more or less avoidable forms of waste, as distinguished from those necessary and unavoidable wastes indicated by the pure theory of thermodynamics. The first and second of these divisions are treated of in works on thermodynamics, and in treatises on physics. The third division is briefly considered, and usually very incompletely, in treatises on the steam-engine; while the last is of too recent development to be the subject of complete treatment, as yet, in any existing works.

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"Of all the heat sent forward by the steam boiler to the engine, a certain part, definite in amount and easily calculated when the power developed is known, is expended by

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* *Transactions* British Association for Advancement of Science, Montreal Meeting, 1884; *Journal Franklin Institute*, October, 1884; Manual of the Steam-Engine, Chap. III.

transformation into mechanical energy; another part, equally definite and easily calculated, also, is expended as the necessarily occurring waste which must take place in all such transformations at usual temperatures of reception and rejection of heat; still another portion is lost by conduction and radiation to surrounding bodies; and finally, a part, often very large in comparison with even the first and principal of these quantities, is wasted by transfer, within the engine, from the induction to the eduction side, 'from steam to exhaust,' by a singular and interesting process, without conversion into useful effect. The science of thermodynamics only takes cognizance of the first, which is sometimes one of the smallest of these expenditures. The science of the general physics of heat takes cognizance of the others.

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"Chronologically considered, the history of the growth of the theory of the steam-engine divides itself distinctly into three periods: the first extending up to the middle of the present century, and mainly distinguished by the attempts of Carnot and of Clapeyron to formulate a physical theory of the thermodynamics of the machine; the second beginning with the date of the work of Rankine and Clausius, who constructed a correct thermodynamic theory; and the third beginning a generation later, and marked by the introduction, into the general theory, of the physics of the conduction and transfer of that heat which plays no part in the useful transformation of energy. The first period may be said to include, also, the inauguration of experimental investigation, and the discovery of the nature and extent of avoidable wastes, and attempts at their amelioration, by James Watt and by John Smeaton. The second period is marked by the attempt on the part of a number of engineers to determine the method and magnitude of these wastes by more thorough and systematic investigation, and the exact enunciation of the law governing the necessary rejection of heat, as revealed by the science of thermodynamics. The third period is opening with promise of a

complete and practically applicable investigation of all the methods of loss of energy in the engine, and of the determination, by both theoretical and experimental research, of all the data needed for the construction of a working theory.

"M. Hirn has recognized these three periods, and has proposed to call the second the 'theoretical' and the third the 'experimental' stage. The writer would prefer to make the nomenclature somewhat more accordant with what has seemed to him to be the true method of development of the subject. It has been seen that the experimental stage really began with the investigations of Watt in the first period, and that the work of experimentation was continued through the second into the present, the last period.

"It is also evident that the theoretical stage, if it can be properly said that such a period may be marked off in the history of the theory of the steam-engine, actually extends into the present epoch, since the work of the engineer and the physicist of to-day consists in the application of the science of heat-transfer and heat-transformation, together, to the engine. During the second period, the theory included only the thermodynamics of the engine; while the third period is about to incorporate the theory of conduction and radiation into the general theory, with the already established theory of heat-transformation. The writer would, therefore, make the classification of these successive stages in the progress here described, thus:

"(1) Primary Period.—That of incomplete investigation and of earliest systematic, but inaccurate, theory.

"(2) Secondary Period.—That of the establishment of a correct thermodynamic theory, the *Theory of the Ideal Engine.*

"(3) Tertiary Period.—That of the production of the complete theory of the engine, of the *true Theory of the Real Engine.*

The work of developing this theory is still incomplete. It remains to be determined by experiment precisely what are the laws of transfer of heat between metal and vapor, in the engine cylinder, and to apply these laws in the theory of the machine."

In the present paper are exhibited the later developments of the study of the heat-wastes of the engine, the scientific discussion of which is expected ultimately to supply the still missing link in the theory of the real engine as distinguished from the ideal thermodynamic machine, and which may thus, perhaps, ere long, permit the construction of a complete and rational theory of the heat-engines, including the physical as well as the thermodynamical elements of that complete theory.

HEAT-WASTES OF THE STEAM-ENGINE.

The following preliminary study of the facts of the case, as illustrated by the action of several different classes of engine, may prove interesting, and possibly useful, as leading the way to the more exact quantitative investigation that must ensue to give us the desired mathematical expression of the quantity and rate of heat exchange. The method pursued is the familiar one of laying down a "saturation curve"—exhibiting the variations of pressure and volume of the given weight of steam, constituting a working charge, when retained in the "dry and saturated state" throughout the range of volumetric change illustrated in the engine cylinder, and as shown on the indicator diagram—and placing beside it the expansion line of the diagram itself. The relative magnitudes of the volumes indicated on the curves of the diagram, and on the standard thus laid down, being taken at a common pressure in each case, measure the proportions of steam existing in the mixture in the engine cylinder at the instants taken. The variations of this proportion measure in turn the variations of composition of the working charge. The "quality" of the fluid is thus at every instant determinable, and is customarily measured as a fraction, completely dry steam being taken as unity. The several figures given herewith illustrate this method clearly. The value of the saturation curve as a base line, or reference curve, was, perhaps, first revealed by Professor Cotterill. It has been used extensively in Sibley College work, in connection with such investigations as those here in part described, and the Col-

lege has made it a standard system of measurement of heat and steam variations, for a considerable time, in the work of the Department of Experimental Engineering.* The use of the adiabatic expansion curve, in a similar manner, permits the comparison of the work performed in the actual case with that which would be done by the same weight of steam supplied to a non-conducting cylinder, as well as the amount of initial condensation.† It does not, however, permit the determination of the quality of the steam and its variations throughout the stroke, which is what is here required. In many cases a simple equilateral hyperbola will give a reference line of sufficient exactness of location for the purposes of the engineer, as the indices of the three curves only vary as the numbers 1·000, 1·0646, 1·135, and for moderate ratios of expansion the lines are very nearly coincident. For present purposes the saturation line, and that laid down with extreme accuracy, is what is required, and this has been obtained in the accompanying illustrations.

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It is also instructive to draw the adiabatic curve, as above stated, in illustrating the changes which would occur could the same quantity of steam be worked in a non-conducting cylinder, and all wastes by heat exchange between steam in the engine and the metal of the cylinder thus be avoided. This would also show, by its departure from the saturation curve, with which it would be coincident at its beginning, the amount of thermodynamic condensation—that produced by conversion of internal energy into the work of adiabatic expansion.

These methods, and the results of their application to a few specially interesting and typical cases, will be illus-

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* See Cotterill, second edition. This system was referred to by the writer in the discussion of the paper on the Milwaukee pumping engine, where the question of best methods of combining multiple-diagrams came up (*Transactions* American Society of Mechanical Engineers, Vol. XV).

† For an example of this application see Manual of the Steam-Engine, Vol. I, pp. 406, 407.

trated in the following examples, each of which appertains to a familiar and important class of steam-engines. They are especially instructive, as applied to the multiple-cylinder engine, in which the action of heat transfer and of heat transformation has hitherto remained somewhat obscure, in the absence of such studies of the facts of their operation, cylinder by cylinder. In this application it will be noted that the saturation curve for the combined diagram must usually be discontinuous, as only absolute equality of clearance and compression and of steam condensation can give perfect continuity.

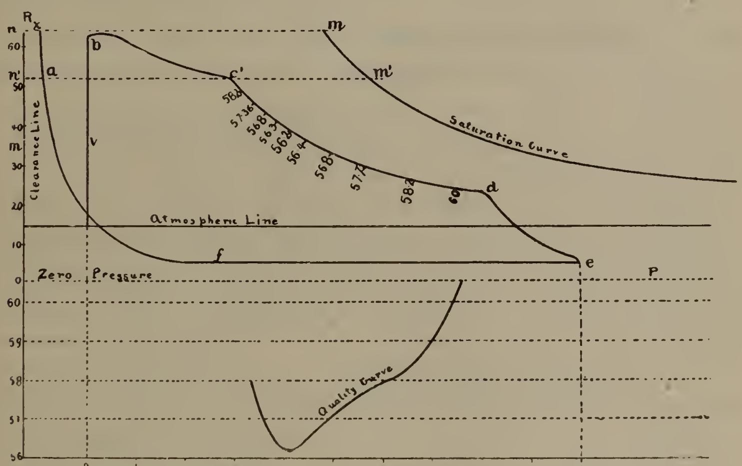

FIG. 1.—Single-valve engine diagrams.

Fig. 1 presents the diagrams from a small, plain slide-valve engine, of 6-inch diameter of piston, and 8-inch stroke; cut-off set at three-tenths, making 208·4 revolutions per minute, and consuming 39·7 pounds of steam per horse-power per hour. The compression line of the indicator diagram is carried up to the steam line to determine the quantity in the clearance spaces, and the amount admitted to cut-off; and the saturation curve for this weight of steam is laid down at the right of the diagram, in such manner that the co-ordinates of the expansion line of the latter and those of the saturation curve shall coincide in magnitude in measuring the varying pressures, and shall

have the proportions of volume of mixture to that of the fluid, when completely vaporous, on the horizontal scale. Below, with its corresponding ordinates in line with those of the indicator diagram, is the "quality curve," exhibiting the variation of quality of steam, with progressing expansion, from the point of cut-off to the end of the expansion period, outside which range this variation cannot be traced on the diagram.

The interesting facts brought out by the comparison of the expansion line of the diagram with the saturation curve of the charge, are the extensive initial condensation, the passage of the fluid through a point of maximum depreciation of quality, of maximum condensation, after the point of cut-off is passed, and the gradual recovery of quality to the end of the expansion period; and, finally, the most instructive fact that, even at the opening of the exhaust-valve, the re-evaporation is barely sufficient to restore the quality of the steam as observed at the instant of closing of the cut-off valve. In this case, at least, the assumption, commonly made, that the condensation at cut-off represents a complete waste of heat and steam, is justified completely. The "quality curve," below, is determined by a sufficiently numerous collection of data, and enables us to locate the point of inflection and of maximum condensation at almost precisely 0·4 stroke. It is at this point that Engineer-in-Chief Isherwood, U. S. N., located the cut-off of maximum effect in engines of this class and in marine engines of the older types. The condensation at cut-off is here 42 per cent., increasing from cut-off at 0·3 stroke, to the maximum, 44 per cent. at 0·4 stroke, and then decreasing, by re-evaporation, to 40 per cent. at the end of the expansion period. The varying speed of piston, and changing temperatures of the gradually uncovered surfaces of the cylinder wall produce a curious wave in the quality curve, and this may be used to obtain approximate measures of temperatures of metal along the cylinder, and of rate of heat-transfer between metal and steam.*

* It will be noticed that the atmospheric line is set at a barometric pressure of 14·42 pounds per square inch. This comes of the fact that the engine is operated at an elevation of several hundred feet above the sea-level.

This illustrates the behavior of an unjacketed cylinder, and the small size of the machine, by exaggerating the action of the metal upon the steam, permits its illustration much more strikingly than would diagrams from an engine of large size.

It is seen that only about 5 per cent. of the total internal waste occurs, in this case, after the close of the cut-off valve. It is further to be especially noted that the steam lost up to the point of cut-off is not re-evaporated in time to do work upon the piston; but that it is necessarily all re-evaporated after the exhaust-valve opens, and during the return stroke of the piston.

A thermal analysis of the action of this engine, in regular operation, gives the following data:

	Pounds.
Weight of steam used per stroke	0·0126
Weight of steam in clearance	0·00165

	B. T. U.
Total heat supplied	12·857
Loss to metal during admission	5·5114
Returned during expansion	1·3586
Returned during exhaust	3·0365
Returned during compression	0·2973
Waste by radiation	0·8190

These figures reduced to percentages become:

	Per Cent.
Heat supplied to the engine	100·00
Stored during admission	42·88
Restored during expansion	10·57
Rejected with exhaust	23·60
Restored during compression	2·31
Lost by radiation from exterior	5·39
Transformed thermodynamically	5·25
Rejected untransformed	94·75

The mechanical efficiency of the engine is found to be 71·2 per cent.

The accompanying set of efficiency curves (*Fig. 2*) for varying ratios of expansion, based upon the performance of the engine with 85 pounds pressure, absolute, shows the resultant effect upon its efficiency, where *a*, the lower line, exhibits the varying efficiency of the ideal representative as measured in pounds of steam consumed per hour; *b*, the

added tax due to the frictional or dynamic waste, the cost in steam being superposed upon the first curve, and the waste by external radiation added to give *c*, the third line; while the internal wastes similarly added as accessions to the values of the ordinates, giving *d*, the upper curve, we are enabled to read the final costs of operation, in steam consumed in the actual case, for ratios of from unity to twelve.

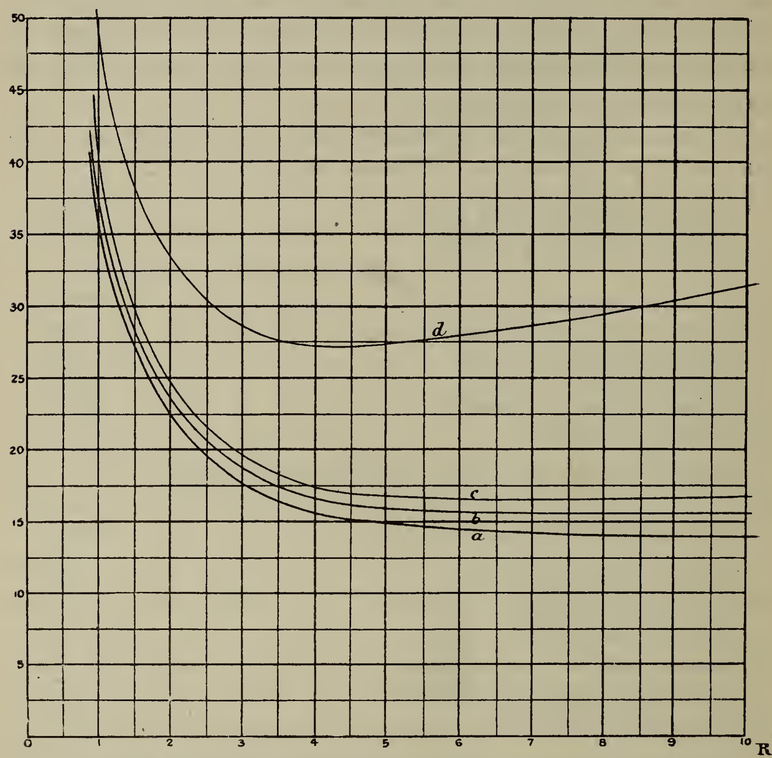

FIG. 2.—Efficiency curves. Small engine ; three-ported slide valves.

An examination of these curves shows that this engine, used in connection with a good condenser, with a back pressure not exceeding 4 pounds per square inch, could all extra thermodynamic wastes be extinguished, would have no ratio of expansion for maximum efficiency within the limits here explored ; that, the friction losses being added,

the net power would be obtained at minimum cost in steam used at about $r = 8$; that external wastes restrict this figure to about 7; that extreme expansion, when internal wastes come into the account, and maximum total efficiency is sought, cannot exceed 4·5 as the highest ratio for highest "duty." This exhibits very effectively the influence of the several wastes upon small engines of this class. The ideal thermodynamic case would demand but about 14 pounds of steam per horse-power per hour; while the added wastes of the real case, mainly losses by heat exchange between steam and cylinder wall, restrict the expansion to a ratio not exceeding 4½, and raise the steam consumption to 27 pounds at highest attainable duty, doubling the cost of fuel and steam.

* * * * * * *

Fig. 3 illustrates the application of these methods to an engine of highest type of contemporary construction, three cylinders in series, and employing high-pressure steam with a large ratio of expansion. It is the combined diagram of a pumping-engine, beside which are laid down, by the same hand as in the preceding case, the adiabatic for the total steam used, the saturation curve for the working charge, and the hyperbolic line for equal initial volume of charge. The adiabatic here shows the work which would have been performed in a structurally perfect engine of the same cycle, free from extra thermodynamic wastes, by an equal weight of steam from the boiler; the saturation curve exhibits the effect upon the actual charge of working steam of the heat transferred from the jacket; and the hyperbolic curve may be taken as a kind of base line, a standard of comparison for all. The steam supplied is taken as containing less than 2 per cent. water. The figures on the margin of the indicator diagram, in each case, are those of quality of steam.

The saturation curve is here discontinuous, for the reasons already given; the other curves are continuous. All follow the same general trend; they coincide at about the middle of their length and there cross, separating slowly

to the end, but are never far apart at any point. The hyperbolic line is the most nearly approximate to the path of the expansion lines of the diagrams given by the indicator. The departure of the saturation and adiabatic curves at their upper limits measures the proportion of jacket steam, which is included under the latter, but not under the former, since it is desired to exhibit, by the standard given by the saturation curve, the heat flow between working charge and jacket steam, and the variation of quality of the working steam. The zero line of pressure is here 14·5 pounds below atmospheric pressure, as shown by the barometer, properly corrected, at the time of the trial at which these diagrams were taken. The diagrams, on the whole, are remarkable for the exceptional fulness of the actual, as compared with the ideal total-work diagram, for the small amount of initial condensation, for the uniformity of this condensation in the several cylinders, and for the minute loss by drop of pressure between cylinders. The engine itself is remarkable for the smallness of its clearance volumes, the promptness of cut-off, the effectiveness of its jacketing, and the general excellence of design, which enables the ideal to be so nearly approached. The low back pressure is one of the most noticeable points to be observed in this case. The most essential quantities are inscribed on the diagram in *Fig. 3*, which may be studied as an unexcelled approximation to that perfect distribution and utilization of steam which the engineer is constantly seeking.*

Computing the efficiency of the ideal representative case for this engine, and the wastes of the real engine, and comparing them with the results of test, the figures given in the succeeding table are obtained. The wastes are computed for the low-pressure cylinder, and the assumption is made that all work is performed in that cylinder. The dynamic waste is taken, at the usual rating of the engine,

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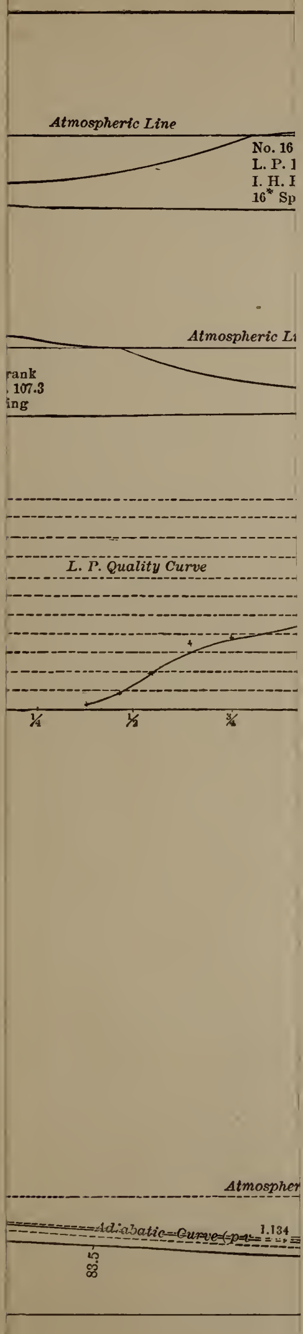
* An account of this engine is given by the writer in the paper "On the Maximum Economy of the Contemporary High-pressure Steam-engine;" *Transactions* Am. Soc. Mechanical Engineers, 1893.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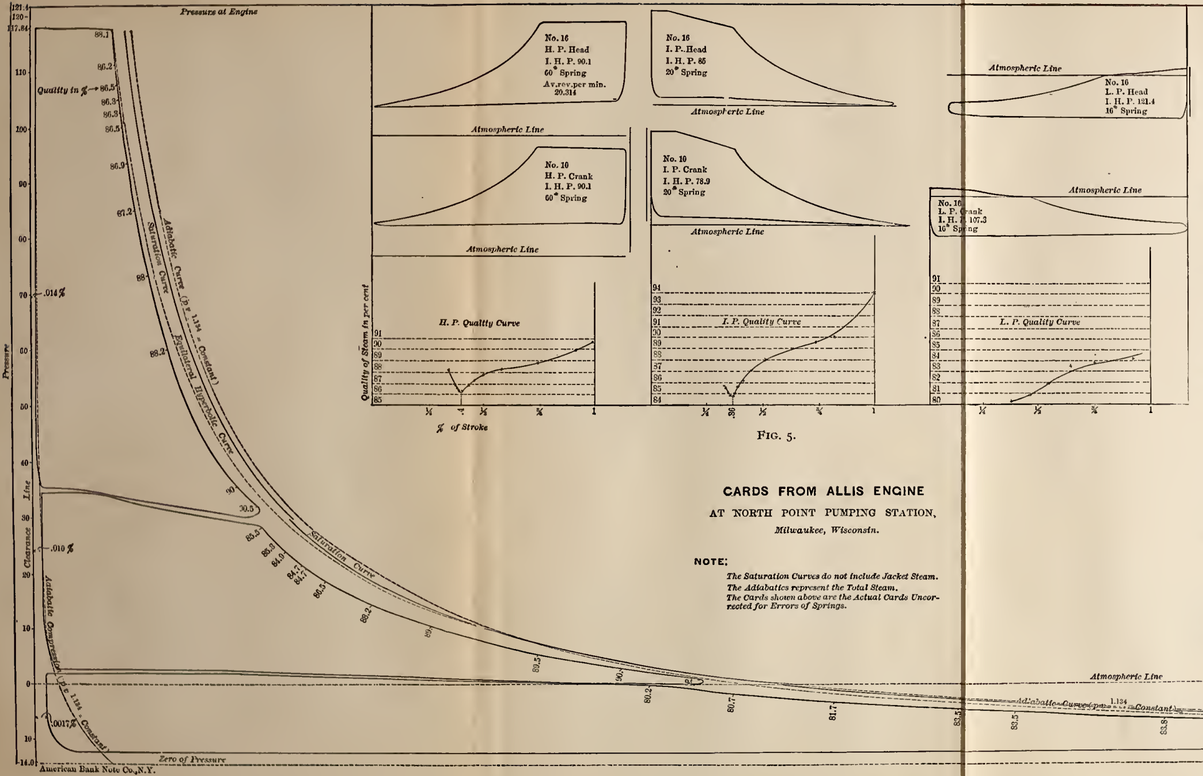

FIG. 5.

The accompanying plate presents a very accurately-constructed set of combined average diagrams, corresponding very closely with the mean for the trial and with the Thermal Analysis, Appendix D, as prepared for the writer by Mr. Thos. Hall, and with the appropriate saturation-curve for the working steam and the adiabatic expansion-line for the total steam per stroke, laid down for comparisons. There are also given copies of a set of the separate mean indicator diagrams, with the curves deduced from each, exhibiting the varying quality of steam throughout the stroke in each cylinder.

In the first diagram the varying departures of the expanding masses of steam from the dry state are beautifully shown by the separation of the expansion-lines of the diagram from the saturation-curve. The breaks in this curve are due to the differences in clearance volumes and compression in the several cylinders. The adiabatic shows the limit of complete utilization of steam and the total loss of effect by internal wastes. The hyperbolic curve also serves for further comparison, and shows how far the actual deviates from the hyperbolic expansion curve. The distribution of power and adjustment of expansion between the cylinders is well exhibited, as well as the varying heat-flow between steam and cylinder-wall with progressing expansion.

The other diagrams illustrate an especially interesting point—the passage of the point of cut-off in the high-pressure cylinder before cylinder-condensation ceases, as shown by the cusp in the high-pressure quality-curve, and to a less extent in the intermediate cylinder. It does not appear in the low-pressure diagram. Each, in order, shows this more and more rapid and extensive restoration of heat from water to steam, after cut-off, and the final drying of the working-charge, by heat received from the jacket, throughout the whole length of the line on the low-pressure diagram.

Measuring the ideal diagram between the adiabatic expansion and compression lines, we find the real diagram to have 80.53% of its total area. Otherwise stated, the losses by condensation and drop in the engine, as constructed and operated, amount to 20% of the available energy of the steam supplied.

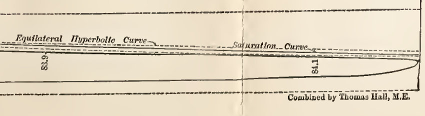

FIG. 3.—Combined multiple-cylinder diagrams.

as 10 per cent. of the delivered power; the internal heat wastes are computed by the formula*

$$c = a \frac{\sqrt{r\,t}}{d}$$

in which a is taken, as in the Sandy Hook experiments, as 4, and $r = 19{\cdot}55$, $t = 2{\cdot}96$;

$$c = 4 \sqrt{\frac{2{\cdot}23 \times 2{\cdot}96}{74}} = 0{\cdot}13932$$

External wastes of heat are taken as 0·5 B. T. U. per square foot of exterior surface, and per degree difference between external and internal temperatures:

COMPARISON OF IDEAL AND REAL ENGINES.

Size of engine	28 + 48 + 74 × 60 inches.
Real ratio of expansion	19·55
Mean effective pressure, ideal case	25·00
Mean effective pressure, real, computed	18·99
Mean effective pressure, real, observed	21·80
I. H. P., ideal	660
I. H. P., real, computed	567
I. H. P., real, observed	573·9
D. H. P., ideal	660
D. H. P., real, computed	501
D. H. P., real, observed	520·9
Dry steam, per I. H. P. per hour, ideal	8·90
Dry steam, per I. H. P. per hour, real, computed	11·73
Dry steam, per I. H. P., per hour, real, observed	11·68
Heat, B. T. U., per I. H. P. per minute, ideal	167
Heat, B. T. U., per I. H. P. per minute, real, computed	220
Heat, B. T. U., per I. H. P. per minute, real, observed	217·6

The curves of efficiencies (*Fig. 4*) illustrate the action of this engine very perfectly. The lower curve is that of steam consumption of the ideal case, the next the dynamic wastes, the third is the external thermal loss, and the upper is that of the internal thermal wastes, each quantity being superposed on the preceding in such manner that the ordinates of the highest curve give the computed, and approximately the real, steam-consumption of the engine at the ratios of expansion corresponding to their location. It is

* Manual Steam Engine, Chapter V.

seen that the real engine has a maximum efficiency, thus measured, at a ratio of expansion of about 20, the ratio actually adopted by the builders. The fact that its record is the best yet registered is good evidence that the conclusion thus derived is substantially correct. The upper dotted line in the diagram is that representing the internal thermal wastes of the engine, as computed on the assumption that all work is done in the low-pressure cylinder, converting the machine into a simple engine. It exhibits the wide difference in final efficiency produced by the cascade

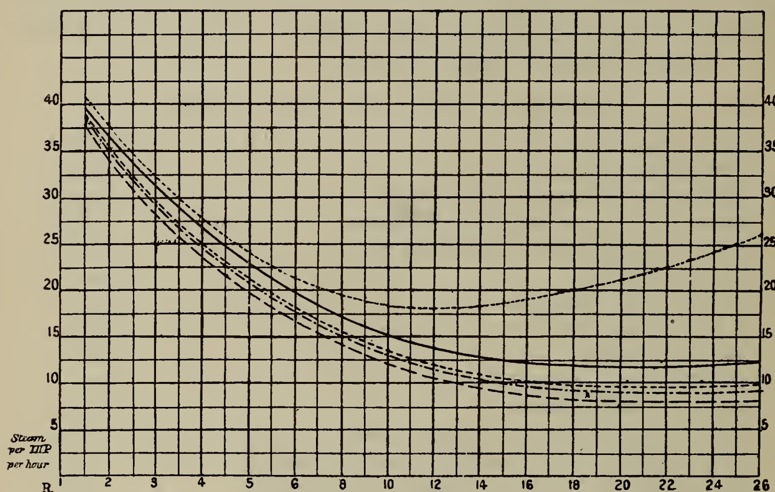

FIG. 4.—Efficiencies of triple-expansion engine.

action of the multiple-cylinder engine, while the effect on the best adjustment of cut-off is brought out very strikingly also.

The fac-similes of the diagrams taken from the several cylinders which are combined in the preceding illustration, and the quality curves which are obtained from them, are given on *Fig. 5*. The engine has steam cylinders, 28 inches, 48 inches and 74 inches in diameter, and is of 60 inches stroke of piston, carrying 120 pounds steam-pressure at the steam-chest, and making 20·3 revolutions per minute when giving a duty of 154,448,000 foot-pounds per 1,000 pounds of dry steam supplied. The set of diagrams here given repre-

sents a very fair average for that engine, but is simply illustrative of the subject of this paper, and is not selected for any other purpose. The essential data are inscribed on the diagrams. Below each pair is placed the "quality curve" obtained as their average. These quality curves exhibit beautifully the action of heat-exchange in the successive elements of the series, and the effect of the jacket in modifying the extent and rate of transfer as illustrated in the simple unjacketed engine first considered.

In the high-pressure cylinder the same general method of heat-exchange is seen, but the condensation ceases more nearly at the point of cut-off than in the first case. The cusp is no less certainly present, but its extent is reduced by the action of the jacket, which, however, is not very active in the high-pressure cylinder usually. In this respect this case is exceptional, as the initial condensation is here less than 12 per cent. The same wave in the line between the point of the cusp and the terminal of the curve is here seen that was observed in *Fig. 1*. The curve, as a whole, has the same form as in that figure, but its variations of curvature are less extensive, and the heat-exchanges, therefore, correspondingly less serious in reduction of the efficiency of the engine. The same fact is here seen relative to the change of "quality" between cut-off and exhaust. The total change is from 88 to 90·5, notwithstanding the effectiveness of a jacket which held down the initial condensation to 12 per cent. These facts indicate the small amount of heat transferred from jacket to working steam in the high-pressure cylinder, and the correctness of the assumption that the quantity of condensation at cut-off measures the internal waste with substantial accuracy. Correcting for the concealed effect of thermodynamic condensation, here amounting to about 8 per cent., it would appear that the jacket and re-evaporation together transferred heat enough to the charge to improve its quality about 10 per cent. in the absence of adiabatic condensation. The cut-off here takes place at one-third stroke; the maximum condensation occurs at four-tenths, precisely as in the unjacketed engine.

The intermediate cylinder exhibits the cumulative effect of jacket action in the reduced extent of the cusp, its earlier occurrence after cut-off, and the larger improvement in quality of steam between cut-off and exhaust, which here amounts to above 8 per cent. The same wave is seen as in the preceding cases, indicative of variation of relative velocities of piston and of heat-exchange. Cut-off here takes place at 0·34, and the cusp is found at 0·36. Thermodynamic condensation should increase the waste from the 13 or 14 per cent. at cut-off to about 18 per cent., while the actual change is an improvement of 9 per cent., showing jacket-action and re-evaporation to have transferred to the steam nearly 15 per cent. of the total heat energy in the engine. The curve for the low-pressure cylinder shows still further progress in the same direction. The cusp has disappeared, the steam is continuously dryer as the piston moves from cut-off to the end of stroke, and the improvement in quality amounts to about 10 per cent., notwithstanding a further thermodynamic condensation of about 5 per cent. Jacket action is more effective in the intermediate than in the high-pressure cylinder and receiver, and still more so in the low-pressure receiver and cylinder. In this engine, taken as a unit, the adiabatic condensation is about 17 per cent., and the jacket holds down the initial condensation to 12, the final to 8, counteracting, at the same time, the adiabatic condensation, and thus giving a total heat-transfer sufficient to vaporize a net 20 per cent. at final exhaust, of which 9 per cent., as measured, comes from the jacket itself, and the remainder from the heat-store previously taken into the cylinder walls. This latter quantity, 12 per cent. at the start, is thus probably largely re-transferred before exhaust, a fact apparently indicating the complete drying of the surfaces of the cylinders previous to the opening of the exhaust-valve on the low-pressure cylinder.

The final net result may be stated thus: The supply of 9 per cent. of the steam to the jackets, in this case, produced a reduction of initial condensation, from a probable 30 per cent. at the beginning of expansion, to 12, and counteracts thermodynamic condensation to the extent of about 9 per

cent. by transfer of heat to the working steam. Thus, checking thermodynamic condensation results in the restriction of internal wastes by about double the amount of heat so expended through the intrinsically wasteful action of the jacket.

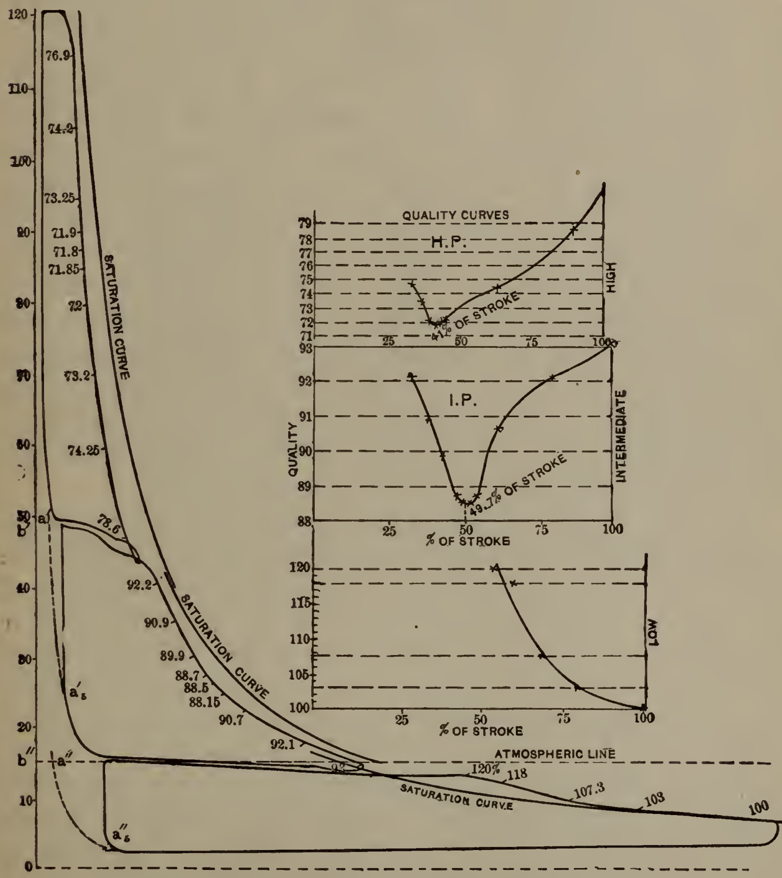

FIG. 6.—Quality-curves of triple-cylinder engine.

The next example is, in some respects, still more interesting, novel and instructive. The combined diagrams (*Fig. 6*) are obtained from the Experimental Engine of Sibley College, Cornell University, and represent the distribution and quality of steam in its passage through the engine,

when the cost of the horse-power was that of 13·3 pounds of dry steam per hour, perhaps the lowest figure ever attained on an engine of such small size and power. This engine has cylinders 9 inches, 16 inches and 24 inches in diameter, and a stroke of piston of 36 inches. It is arranged as three independent machines, which can be combined in any manner desired, and operated with or without expansion, and either jacketed or unjacketed. On this occasion it developed 140·2 I. H. P., 13·72 per cent. of the steam-supply passing through the jackets of cylinders and receivers, all of which had their jackets in action. The saturation curves on the diagram are laid down for the weight of working charge, and are intended to bring out clearly the action of the jackets and cylinder walls in heat exchanges with the steam in the cylinders. The points of cut-off were very nearly at one-third stroke in the high and intermediate, and three-fifths in the low-pressure cylinder. The quality curves are given on the plate, with the combined diagram. The saturation curves on the latter are seen to be discontinuous, and markedly so, in consequence of the differences in volume of clearance and in extent of compression.

At the instant of closing the cut-off valve on the high-pressure cylinder, the steam enclosed contained 25 per cent. water. At four-tenths stroke its quality had depreciated by further cylinder-condensation to 71·8 per cent., and at the end of stroke, by accession of heat from the jackets and restoration from the cylinder wall, it had risen to a trifle above the quality at the start, to about 80 per cent. Practically, it may be said, as before, the condensation at cut-off measures the waste by heat-exchange between steam and metal. In the intermediate cylinder the quality at cut-off, raised to 92 per cent. by the drying action of the exhaust period of the high-pressure cylinder and of the receivers and their jackets, becomes 88 per cent. at half stroke, as a minimum, and then rapidly improves to the end of the stroke, where it is 93 per cent. Here, again, it is found that the waste is measured by the condensation at cut-off. It will be noted that the saturation curve for the intermediate cylinder falls inside the line of that for the high-pressure,

and that the indicator expansion-line falls outside, the two lines being more closely approximated in the case of the intermediate than in that of the high-pressure cylinder.

The low-pressure cylinder presents the most singular departure from the usual case. The saturation curve falls still further inside the lines for the other cylinders, the expansion line of the diagram falls entirely outside the saturation curve, showing considerable superheating from the transfer of heat by jackets to the working steam in the second receiver and the large cylinder. But in this case the quality falls off steadily from the moment of closing the steam-valve. From an initial 120 per cent., it becomes 107 at three-quarters stroke, and unity at the end, leaving the engine precisely dry, a condition asserted by some writers on the subject to be that of highest effectiveness of jacketing. The location and the depth of the cusps in these diagrams are also indicative of the action of the jackets. The jacket on the high-pressure cylinder is seen to be quite effective in checking the heat-exchange to metal; that of the first receiver and that on the intermediate cylinder seem to be of less effect, possibly in consequence of the dryer steam; and the jackets on the second receiver and the low-pressure cylinder are found to be of extraordinary activity.

The outcome of the peculiar and interesting distribution of heat and steam in this case is a very remarkable efficiency of engine, and an unexampled low figure for steam consumed. So far as it goes, it corroborates the conclusion that the jacket does its best work when it gives dry and saturated steam at the instant of exhaust. In the high-pressure and intermediate cylinders, as in the three cylinders of the preceding case, and in the single cylinder first studied, we find that the loss by initial condensation is measured with substantial accuracy by the condensation at cut-off; but in the low-pressure cylinder in the last example, the large flow of heat from the second receiver and third cylinder jackets sensibly modifies this result. The total condensation in the jackets amounts to 13·72 per cent. of the whole steam supply. Of this one-fourth was condensed in the high-pressure jacket, one-twelfth in the intermediate, and

one-third in the low-pressure, while the balance was condensed in the receivers, in the proportion of over three to one in the second. The low-pressure jackets and second receiver take about one-third of all steam sent into the jacket system.

The pair of diagrams (*Figs.* 7 and 8), with their respective quality curves, illustrate the effect of a process of reduction of internal waste which has been often proposed, but, perhaps, never before actually attempted. It involves the regulation of the engine by variation of the compression

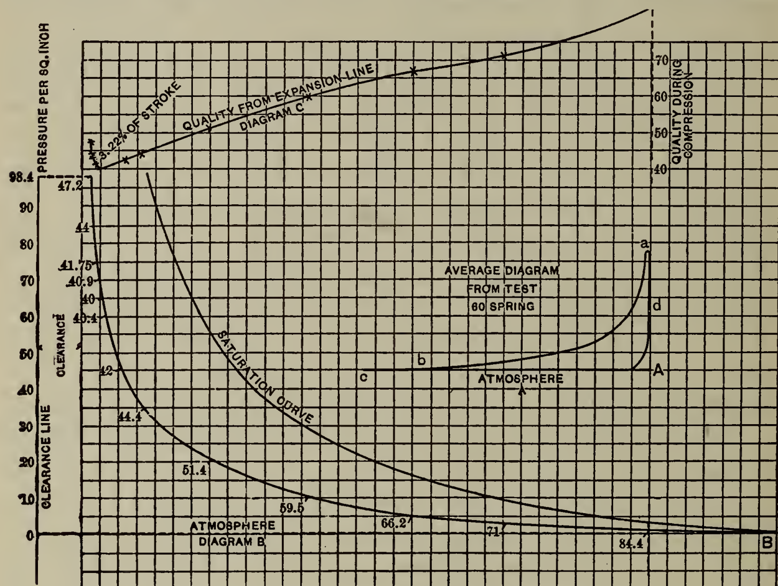

FIG. 7.—Heat exchanges with large expansion.

line, instead of, as usual, by the adjustment of the ratio of expansion to the momentary variations of load. The question to be settled by the examination of these diagrams is simply whether high compression will reduce the initial condensation, and thus effect economy, where it is well known that high expansion causes loss.

* * * * * * *

The same cusp which has been previously observed is here distinctly exhibited. With the extreme expansion

here adopted, it is also clearly seen that re-evaporation not only restores the initial quality of the steam, but greatly improves it, in spite of the resisting action of thermodynamic condensation; and the quality varies from 47 at the instant of closing the steam-valve, to 40 at one-thirtieth stroke, to 66 at about half stroke, and to 84·4 per cent. at the end. About two-thirds of the condensed steam is re-evaporated in the expansion period. In the second illustration, the same power is obtained from the engine, and at the same speed, the brake being adjusted to the same load, and

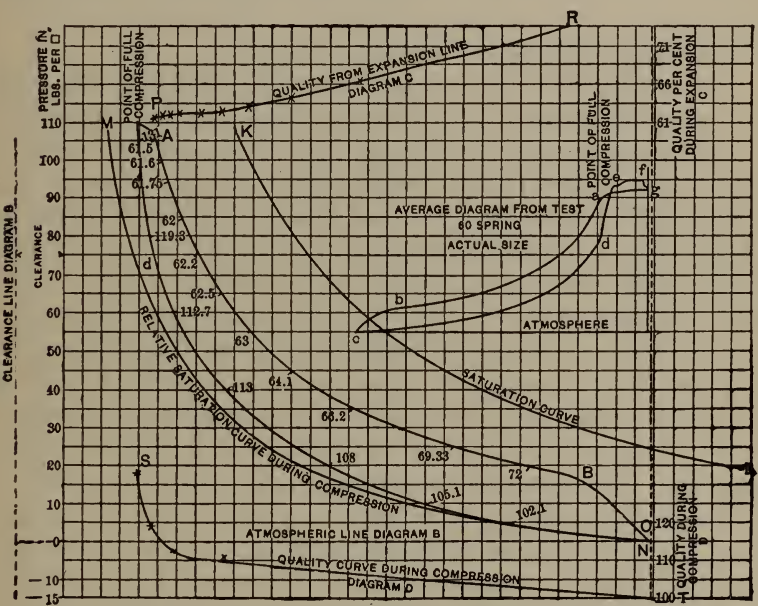

FIG. 8.—Heat exchanges with large compression.

the compression and expansion lines are so adjusted as to give the diagram shown, at the power required. Compression is carried up to boiler pressure, and the expansion line made what is found desirable to give the power considered likely to prove a minimum, or nearly so. The effect upon cylinder condensation is seen to be marked, and precisely what had been anticipated. The cusp has disappeared, and the quality of the expanding steam now rises steadily from the first, from about 60 to above 70 per cent., in the course

of the period of expansion. The condensation has been reduced from 53 to 38 per cent.; the improvement in quality amounts to 14 per cent. at the beginning of expansion, and the two curves exhibit equality at about three-quarters stroke, while the first of the pair is better by over 10 per cent. at the end. The gain of nearly 30 per cent. in the reduction of initial condensation is the important feature; but the comparatively small re-evaporation during expansion is singular and interesting, especially when it is compared with the large re-evaporation observed in the preceding instance. The prediction of reduced wastes is here evidently confirmed.

An inspection of the compression side is most instructive. The saturation curve is laid down beside and below the line of compression, and the quality curve obtained is seen at the bottom of the plate. Beginning with the close of the exhaust-valve, the quality of the steam, initially assumed as unity, rises, by superheating, from the very start. This superheating amounts to about 10° at mid-stroke, to 20° at three-quarters, to 25° at seven-eighths the compression stroke, and to above 60° F. at full compression and boiler pressure. The rise is comparatively slow during the greater part of the return stroke, but suddenly takes on a rapid acceleration at about nine-tenths stroke, and thence rises with extreme rapidity. The cause of this sudden alteration of the law of variation of quality, if it be such, is presumably the attainment of the dry and saturated state, the primary assumption being inaccurate, and such dryness of the steam in contact with the cylinder wall, previously remaining more or less wet, that heat can no longer readily be transferred to the metal, and the whole work of compression is effective by transformation of dynamic into thermal energy. It is this earlier transfer of heat of compression to the metal, and the resultant dryness of surface, with increased temperature, which, as was anticipated, gives the economy seen on the steam side after the opening of the induction-valve.

* * * * * * *

The following are the principal elements of the performance of this engine under the usual conditions of operation

and at various ratios of expansion, both as computed by the now familiar methods pursued in the Sibley College laboratories, and long ago introduced by the writer, and as observed in formal trials.* The internal wastes are computed from the expression

$$c = a \sqrt{r t}$$

in which a is taken as 22·5 per cent. There were noted:

Boiler pressure, by gauge, pounds per square inch	100
Revolutions per minute	86
Quality of steam at engine, per cent.	98
Back-pressure, pounds per square inch	5
Friction of engine, per horse-power	7·25

The following table gives the results of computation beside those of observation:

ECONOMICS OF IDEAL AND OF REAL ENGINE. (9 IN. × 36 IN.; 86 REVS.)

Expenditures in Pounds of Steam per Horse-Power per Hour.

Ratio of Expansion.	Ideal.	Frictional Loss.	Radiation.	Initial Condensation.	Real Engine. Computed.	Real Engine. Total Observed.
	Lbs. Steam.	*Lbs. Steam.*	*Lbs. Steam.*			
1	32·91	1·73	·267	7·62	42·63	—
2	20·50	1·75	·268	6·68	29·18	29·1
3	16·70	1·78	·268	6·70	25·45	24·6
4	15·11	1·80	·270	7·01	24·19	23·1
5	14·21	1·83	·271	7·40	23·71	22·6
6	13·52	1·86	·272	7·70	23·35	22·8
8	12·67	1·98	·275	8·27	22·20	23·7
10	12·22	2·12	·280	9·10	24·08	24·0
12	11·90	2·37	·291	9·50	24·06	24·5
15	11·70	2·71	·305	10·30	24·92	25·5
20	11·61	3·06	·331	12·00	27·00	28·0

The engine trials showed a slightly more rapid gain in the earlier cuts-off, and a greater waste in the later, than were computed; but the two sets of figures are closely accordant throughout, indicating the practicability of securing a measure of the constants, in the expressions for

* Manual of the Steam Engine, Vol. I, Chaps. IV, V.

wastes, by a single trial at any convenient and usual load, and thus a clue to the behavior of the engine at all loads. This fact is of great importance where questions of relative efficiency and costs arise in adjusting sizes and steam dis-

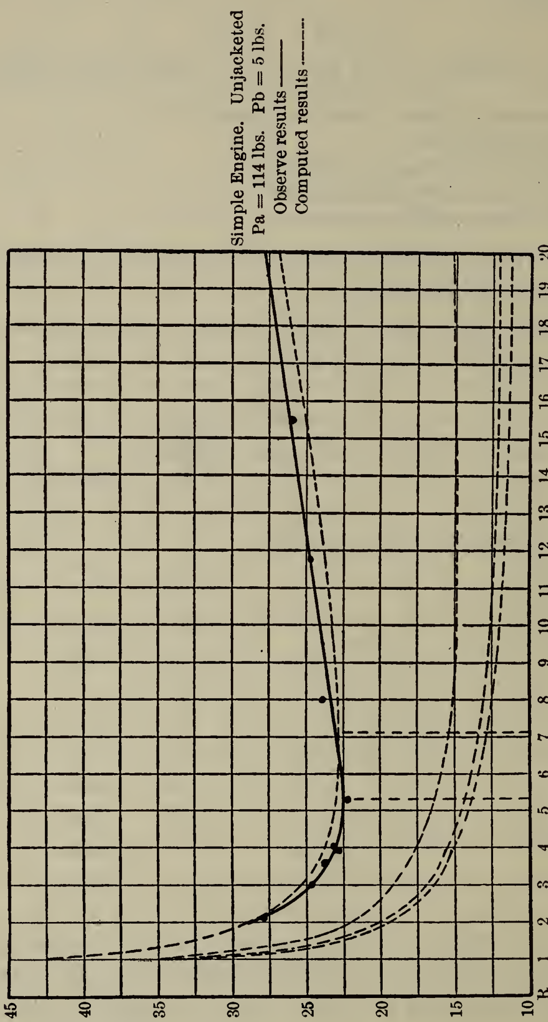

Fig. 9.—Efficiencies of Corliss engine.

tributions of engines to changed or to very variable loads. The two sets of results, computed and observed, are well shown in *Fig. 9*, arranged like the first presented herewith. It is seen that the maximum efficiency is attained in the

computed case at a ratio of expansion of 7, while the engine actually does its best work at about 6. This indicates a greater proportional initial condensation at cuts-off near the beginning and the end, and less at the intermediate portions of the stroke than the assumed hyperbolic law of our formulæ would give; and this conclusion is confirmed by many experiments on a great variety of engines and under very various conditions of operation.

The introduction of high compression in regulation—which was long since proposed by the writer*—as experi-

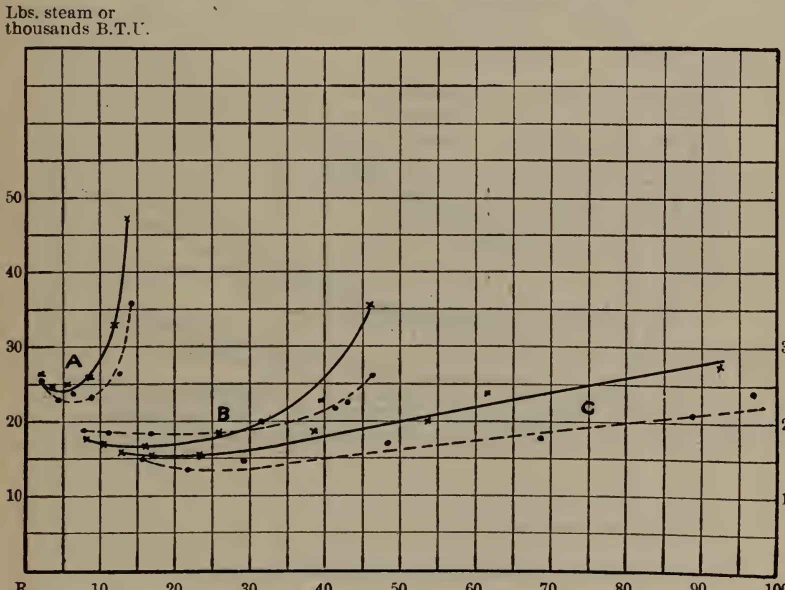

FIG. 10.—Efficiencies of multiple-cylinder engine.

mentally tested by Prof. J. H. Barr, whose work is illustrated above, would presumably improve the action of the engine economically, by depressing the whole upper line of the last diagram and straightening it, and especially by giving it an improved location at the end nearest the commencement of the stroke.†

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* *Transactions* Amer. Soc. Mech. Engineers, August, 1881.

† This particular set of experiments, although verifying the predicted effect of the system upon the heat-exchanges and wastes within the cylinder, did not give evidence of a probability that, on the whole, important gains could be thus secured on this size and class of engines.

As illustrating the modification of efficiencies in this engine produced by compounding, *Fig. 10* presents an interesting set of curves of efficiency obtained from the Sibley College experimental engine by Mr. H. K. Spencer, following the methods which have been customary with the writer in such work, and under the conditions of steam-pressure and back-pressure already described. The simple engine does its best work at ratios of about 4 and 6, unjacketed and jacketed, respectively, the minimum cost in steam being 23 pounds steam, about 23,000 B.T.U. per horse-power per hour. The double-cylinder engine brings these

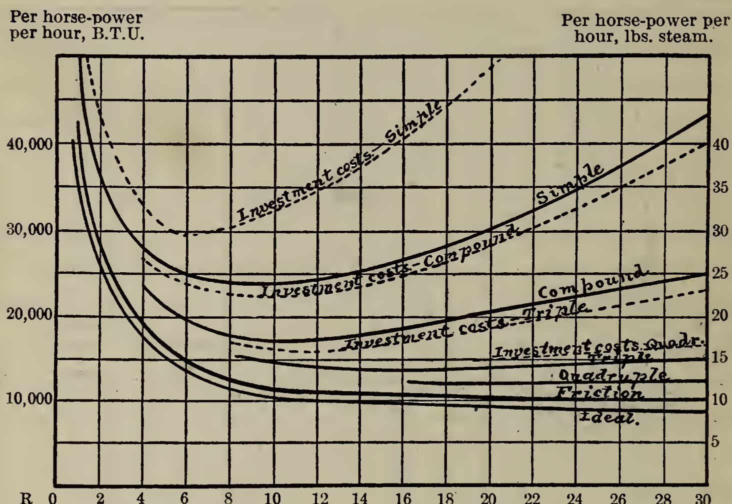

FIG. 11.—Comparative efficiency of engines.

figures up to 12 and 17 for the ratio of expansion, and down to 16 and 18 pounds of steam, and exhibits the anomaly—in this instance the idiosyncrasy—of doing its best work with cylinders and receiver unjacketed at the lower, and the reverse at the higher ratios of expansion. The triple-expansion engine performs its highest duty unjacketed at 20 expansions, jacketed at 22, and at an expenditure of, respectively, a trifle above 15 and 13·3 pounds of steam per hour per horse-power. In the figure the curves *A* are those obtained from the engine when the high-pressure cylinder is worked alone as a simple engine, jacketed and unjacketed;

B is the set of curves obtained from high-pressure and intermediate, working as a compound; and *C* is the set representing the machine as a whole, jacketed and unjacketed, working as a triple-expansion engine, but with only 125 pounds pressure, instead of 175, as originally designed.

* * * * * * *

The following are the data obtained at present when working as last indicated, and under best conditions:*

Cylinders	9 + 16 + 24 × 36 inches.
Piston-rods	2·31 inches diameter.
Vacuum	10·8 pounds, 22 inches.
Jacket water	13·72 per cent.
Total I. H. P.	140·2
Mechanical efficiency	0·88.
B. T. U. per I. H. P. per hour . .	14,160.
B. T. U. per I. H. P. per minute .	236.
Clearances	7·6, 8·93 and 9·35 per cent.
Boiler pressure	pounds, 125 (abs.); 110 by gauge.
Barometer	29·4, 14·42 inches.
Condensing water, per lb. steam .	19 pounds.
D. H. P.	123·4.
Steam per I. H. P. per hour . . .	13·3 pounds.
Steam per D. H. P. per hour . .	15·1 pounds.
Total ratio of expansion	13·83.

Pressures (absolute) at cut-off, 131, 43, 13·5; at release, 43, 14·5, 2·5.

Jacket water, per cent., 26·4, 7·05, 28·1 in cylinders; and 9·85, 34·6 in receivers.

Work, per cent., 1, 1·33 and 1·675, in cylinders 1, 2 and 3.

Thermodynamic efficiency of Carnot cycle, 24·7 per cent.; actual, 18 per cent.; ratio of actual to Carnot, 0·73.

Water-rate of ideal Rankine cycle, 9·6 pounds; ratio to actual, 0·72.

The final effect of the wastes here specially considered, however, can only be discovered in all their bearings when the total variation of costs of power in the engine, with variation of its output, are studied together.

In *Fig. 11*, which concludes this series, are graphically exhibited all the elements which finally determine the costs and profits on the use of the engine, in such manner as to give a clue, if not an exact measure—such as is probably often possible to secure—and thus to enable the engineer

* *Transactions* Amer. Soc. Mech. Engineers, 1894; "Theory of the Steam Jacket," Discussion, p. 879.

to ascertain just how much improvement in economy and efficiency of engine it is financially practicable to demand, what efficiency it will pay to seek. In these curves the variations of each element in the problem are shown by a curve, the ordinates of which are in each case measured from the curve immediately below; in other words, the costs of power are shown in steam or fuel or money, either unit of measure being equally available, provided all are reduced to equivalence. The lowest line is the curve of steam expenditure, and is the ideal case, the purely thermodynamic case, as computed by Rankine's method. The second curve, superposed upon the first, is that which exhibits the added cost of friction of engine in the same unit of measure. The curve marked "simple" is one of which the ordinates, measured down to the friction curve, are proportional to the cost of the wastes in the simple engine by cylinder condensation and leakage, and, by conduction and radiation, the thermal wastes other than thermodynamic. The highest curve is the measure in the same way, its ordinates being measured down to the last-named curve, of the investment costs, which include the interest on first cost, the charges for insurances, rents and other purely financial charges for capital employed in the purchase, installment and preservation of the machine.

It is assumed that the compound engine will approximately divide the cylinder wastes of the simple engine by two, that the triple-expansion engine will have one-third the wastes of the simple, and that, generally, the multiple-cylinder engine will, if properly employed, approximately reduce these internal wastes in the proportion of the number of cylinders employed. This being assumed for an approximation, the curves marked "compound" and "triple" and "quadruple," in full lines, measure, as before, the cylinder wastes of those engines, and the dotted lines, as before, the financial costs of each. The diagram is simply illustrative, but can be easily constructed for any stated case in which the quantities required for its construction can be ascertained, or where any three or four points in each curve can be identified by reference to experiment, or by computation from known data.

The final and essential deductions to be made from this construction are that, while the ideal case, the purely thermodynamic engine, will give increasing efficiencies with increasing expansions indefinitely, the back-pressure not being reached, the introduction of the friction of the engine produces a change, both in the location and the form of the curve, such that, after a time, with increasing expansion, a maximum efficiency is attained, and a minimum cost of power. And, were the curve extended far enough, a point would be found at which the power of the engine would be insufficient, not simply to yield the required power to the belt, but even to turn over the engine shaft alone. With the introduction of internal and other thermal wastes. the maximum efficiency and minimum costs are found at not only a higher figure, but at an enormously reduced ratio of expansion, which, in the case of the simple engine, as here taken, is not far from 8; in the compound, 12; in the triple, 16; and in the quadruple, 22 or 24. When the investment costs are brought into the account, we again have the best ratio of expansion reduced in value; and in the simple engine here taken, it becomes about 5; in the compound, 8; in the triple, 12; and in the quadruple, 16. These figures would vary greatly with the value of fuel and other costs, becoming higher in marine practice than in stationary, for example, other things equal; lower in a coal-mining district than in a country remote from fuel supplies. With coal at $1 per ton, in one case, and at $5 per ton in another, we should probably find the simple engine, on the whole, most desirable, from a financial standpoint, in the one instance, and the quadruple expansion engine the right selection in the other.*

Whatever the location, the conditions of fuel supply or the value of money, the methods here indicated, it has seemed to the writer, may often be found useful in securing the best design and construction of engine, and the highest financial returns on the investment of capital in the provision of power.

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* "Use of Compound Stationary Engines," *Engineering Magazine*, September, 1894.

MODERN THEORIES OF FERMENTATION, WITH NOTES ON THE MORPHOLOGY AND CULTURE OF YEASTS.*

By Dr. Francis Wyatt.

The subject I have chosen to talk to you upon is that of "Germs," those minute living things which are almost inconceivably numerous, and which swarm in endless profusion upon the surface of the earth, and in and beneath the waters.

It is, of course, only natural that infinitely small organisms should enjoy greater advantages than larger ones in the matter of reproduction, because they find food for development more readily, and are more easily carried from place to place. Let me quote two familiar facts as an illustration:

If you allow some spring water to stand in a glass you will notice that it will become green from the growth of small algæ. The germs of these plants were invisible to the eye, but they were either present in the water itself, or were carried into it with minute particles of dust from the air. Again, if you moisten a piece of bread and keep it damp and exposed to the air, a growth of mould will make its appearance. This proceeds from germs of mould fungi derived from the atmosphere.

A very large variety of these germs are extremely common, and have a very wide area of distribution. The general principles of life with them are the same as with higher and larger organisms, and they are, no doubt, similarly affected, though to a less degree, by climatic and other external causes. There is, for example, a very minute fungus, which in some latitudes vegetates on the bodies of living house-flies, and which in other latitudes has never been observed; but on the other hand, the common species

* A lecture delivered before the Franklin Institute, January 10, 1896.

of moulds, such as the *Penicillium glaucum*, are spread all over the world, and can flourish in all climates.

In the present imperfect state of our knowledge of the several species of bacteriæ, it is impossible to make any very precise general statements with respect to the whole of them, but it is safe to say that they are so liberally scattered abroad in every direction, that their appearance at all spots where they find favorable feeding conditions is more than sufficiently explained.

The microscopical investigation into germ life is naturally surrounded by a great many difficulties, and these difficulties can only be surmounted by willing and intelligent students. Sometimes the germs are not present in every smallest spot of earth, air or water, and various devices must be applied to lighten and facilitate the labor of seeking for them. The famous Koch suggested a very ingenious plan which he based upon the fact that gelatine, if combined with some nutrients easily prepared and in a state of solution, becomes a very favorable medium for the development of bacteriæ and non-parasitic fungi. Let us suppose that we are going to examine the air of this chamber. We should draw it very slowly, by means of an aspirator, through a series of glass tubes coated on the inside with properly prepared gelatine, liquefying at a moderate temperature, and becoming stiff when that temperature is lowered. If the inflowing stream is properly regulated, the greater part of the germs which are mixed with the air sink downwards and are caught in the gelatine, where they undergo further development. If the experiment is properly conducted, with a due appreciation of the results desired, and if all disturbing impurities are excluded, quite distinct groups of bacteriæ and fungi will be found in the gelatine after the lapse of a few days, and can be readily seen and counted by the microscope. Each group or colony originated in a germ, or in some cases from an assemblage of germs, which made their way to the particular spot at the commencement of the experiment, and thus the sorting and selection of any particular form of bacteriæ for isolated culture in a subsequent operation become comparatively easy

The two sub-kingdoms of the vegetable world are the flowering plants, or *Phanerogamia*, and the flowerless plants, or *Cryptogamia*, the lowest subdivision of which embraces the *Thallophytes*, having neither leaves, roots, stems nor fibro-vascular tissue. Among the *Thallophytes* have been classed the *Schizomycetes* or *Bacteriæ*, and the *Algæ* and *Fungi*, which include both moulds and yeast.

In very minute forms of life it is difficult to distinguish animals and vegetables from each other, or to select and adhere to any universally applicable definition of species. In the case of the higher plants and animals the line is easily drawn. While the former are able to derive their sustenance from such inorganic compounds as carbon dioxide and ammonia, the latter must have their necessary supply of carbon or nitrogen presented to them in the form of organic compounds. Here, therefore, is a perfectly broad distinction—the plant lives and develops by the assimilation of the elements of carbon dioxide and ammonia, whereas the animal subsists either on vegetable substances or on the bodies of other animals. With the fungi the difficulty of distinction is heightened by the fact that they may, to a certain extent, be said to partake of the nature of both plants and animals; for while they cannot assimilate carbon from inorganic sources, they are able to derive their nitrogenous nutriment from inorganic bodies.

The chemical changes produced during the growth of the *higher* plants result in the building up of complex compounds from the simple ones. The chemical changes involved in the growth and development of animals are the reverse of this, complex bodies being required as nourishment, and being again broken down into simpler ones. The chemical operations of plant life may therefore be regarded as synthetical, while those of animal existence are analytical. The force required by plants, in order to effect the synthesis of their compounds, is probably obtained from the sun, and necessitates a constant absorption of heat. The force exerted by animals in breaking down the complex bodies built up by the plants involves a constant evolution of heat, and thus, as I have said, the fungi occupy the singu-

lar position of combining the vegetable functions of synthesis with the animal functions of analysis.

The *Schizomycetes* or *Bacteriæ* are exceedingly minute bodies, often on the very border line of visibility. They are the cause of putrefaction, as well as of fermentation in the widest sense, such as the souring of milk, the production of vinegar, the decomposition of bouillon, etc. Some species produce disease either in man or animals, or both; some develop pigments, as the red of *Micrococcus prodigiosus*, or the yellow of *Sarcina lutæ;* some cannot exist without free oxygen, and some live for a long time in its absence.

With some species of bacteriæ, as, for example, the so-called "vinegar plant," a gelatinous envelope forms around the organisms at a certain stage of their existence, and an irregular agglomeration ensues, which is termed the zoöglo-ean formation.

A coccus is a circular or egg-shaped cell. Organisms of this kind are found detached, in pairs, fours, packets and strings. A rod-shaped organism, having two parallel sides, is termed either a bacterium or a bacillus. Formerly the very short rods, such, for example, as those whose lengths do not exceed twice their breadth, were termed bacteriæ, and those of greater proportionate length bacilli; but the two varieties are now frequently classed under the latter head, leaving the term bacteriæ free as a general name for the *Schizomycetes*. These organisms divide only in one direction. If the rod is bent it is known as a *vibrio*, and if of corkscrew shape, a *spirillum*, while, if lengthened into a thread or filament, it is spoken of as a *leptothrix* form, which may be either straight, wavy or looped, the leptothrix itself being straight and showing a distinction between base and apex.

Very frequently, though not invariably, bacteriæ exhibit the power of spontaneous movement, in some cases spinning round or darting forward with great rapidity, in others gently undulating, and in others again moving with either a tremulous or gentle sinuous motion. In many instances they are provided with vibratile lashes or flagellæ, by the action of which the movemnt is clearly produced.

Bacteriæ multiply by fission and by the formation of

endospores, the organism in the latter case showing a highly refractory speck, which gradually enlarges, takes a circular or oval form, and eventually appears to absorb the whole contents of the original cell.

The life history of a large number of bacteriæ may be very aptly illustrated by that of the tiny *Monas Dallingeri*, which, measured cubically, is the seventy-thousand-millionth of a cubic inch. It is a long oval, with one motile fiber. The egg-like body is clear, and, to our means of analysis, structureless; in the minutest speck of liquid thousands may be present. Their motion is quick, definite and graceful. While in full motion a change of form, which is somewhat uncertain, takes place in from a minute to ninety seconds, and then the motion becomes slower, the flagellum or motile fiber becomes sluggish in its movement and falls off. We then have a still, flattened, globule. In a few seconds there appears in it suddenly and vividly a white cross, forming two diameters at right angles. Almost immediately after, another cross appears, so placed in relation to the first that they together constitute eight radii proceeding from a common center. This complete, the whole interior substance of the living atom is in a state of movement, which results in its being broken up into a large number of bodies that glide for some minutes over each other, but retain as a mass the globular shape. This suddenly breaks up and sets free a large number, usually thirty-six, relatively small forms, exactly like the original body, of which they are now independent living parts—the thirty-sixth part, in fact, of the primal organism. But they are intensely active, and as they absorb and digest everywhere, and live in their food, they rapidly reach the normal full-grown size; but no sooner is this done than each of these goes again through the same process, and thus the organism multiplies by this means alone in a ratio that is, when not considered as an element of adaptation to its special work in nature, simply astounding. The human population of the globe is immense; yet one of these organisms started to divide in this way at any given moment would, in three hours, have given origin to a host that would equal it. This, however, is not the most

important method, physiologically considered, by which these minutest of living beings increase. It is a process that is exhausting to the vitality of the organisms, and ultimately ceases. But another method is forever at work. When self-division has proceeded for a given time, varying with the species, but always regular in the same species, a marked change takes place in the final fissions; that is, if we follow a dividing nomad when the first division is effected, we can only study one of the divided organisms, the others being free to depart to different directions, each one dividing again. But it is only possible to keep one under observation, and when it divides again only one of the subdivisions can be studied, and so on. But when we reach the last act of fission a change takes place. It does not proceed to divide again, but it becomes more or less unlike the normal form, according to the species. In the case of the *Monas Dallingeri* it grows larger, and the front part of its oval body becomes sparsely granular. It swims with great rapidity, and goes almost immediately into the midst of a group of the ordinary forms. One of these becomes attached to it, and the two swim together, their flagella moving in concert. But it is soon manifest that the substance of the smaller form is melting into the larger, until, in a short time, the two become as one. But there is no loss of action for about two minutes, when the flagella fall off, and a clear, sub-oval globule, perfectly inactive, falls to the floor of the stage. It remains inactive, undergoing no discoverable change for thirty-six hours, and then it bursts, emitting an incalculable host of minute spores, or generic products, which, under observation, rapidly change. They are, when first seen, semi-opaque, globular points, but they rapidly lose their opacity and elongate, passing through successive stages of growth until the full character of the normal adult is attained, when they begin almost immediately to again pass through the self-division into many.

This is a life cycle typical of the entire group of bacteriæ. It thus becomes apparent that the teeming hosts of these putrefactive organisms, as a group, containing the minutest forms accessible to us in nature, have no more caprice in their vital activities than there is in the vermes or insecta.

Their life cycles are as definable as those of a crustacean or a bird. No vital phenomena not to be found amongst higher and larger organisms are observable in this minute field of living things.

The discovery that putrefaction is the result of life and not of death, and that the disgusting phenomena attending the disintegration of dead bodies, whether of plants or animals, is entirely due to the action of microbes, was first made by Theodore Schwann, and it is by no means an uninteresting reflection that if all microbes could be removed and kept away, dead things would never putrefy, but would dry up and remain unchanged year after year until the end of time. The processes of decomposition being stopped, there is no reason to suppose that those of reconstruction would or could go on, and thus there would be an end to the assimilable food for green crops, as well as to that for the myriads of creatures that live upon them.

Within the past year or two some very interesting experiments have been made by the pupils in my laboratory to ascertain the number of germs or microbes contained in the average atmospheric air at midday in populous neighborhoods. In the neighborhood of Fourteenth Street and Sixth Avenue, New York, the results we obtained were as follows:

	Per Cubic Yard.
In January the number of germs of all kinds amounted to . .	3,106
In April the number of germs of all kinds amounted to . . .	4,818
In June the number of germs of all kinds amounted to . . .	5,819
In July the number of germs of all kinds amounted to . . .	5,791
In September the number of germs of all kinds amounted to .	5,900
In November the number of germs of all kinds amounted to .	3,601

I do not give these figures because they have any particular significance in themselves, for the germs were not classified. I merely introduce them because Miquel, of Paris, who has made much more complete and exhaustive experiments, has stated as a fact that the mortality from zymotic and infectious diseases always increases with the number of microbes in the atmosphere. Exactly how his conclusions were formed, I am unable to say; but if he based them on a comparison of mere mortality statistics

covering a certain time, I should be inclined to question the utility of applying them too broadly; because, as a matter of fact, I am not aware that the microbes connected with the common infectious diseases have been discovered in the air, or that they ever exist there outside of the immediate vicinity of the seat of the disease. Miquel has, however, rendered enormous services by his experiments, because they have pointed out how we may avoid the conveyance of microbes into the atmosphere from places where pathogenic forms are known or likely to be present, and have led our sanitary authorities to insist upon vast improvements in the construction and arrangement of hospital wards and of sick-rooms. They have also directed the attention of brewers and distillers and dairymen to the importance of shunning all circumstances tending to disturb and distribute dust in the neighborhood of their factories, and what is still more important, have formed the foundations for the very common use by everybody of antiseptics and disinfectants.

The microbes of the soil are far more numerous and interesting than those of the air; because while some play a most important part in all the processes of putrefaction and nitrification, and are positively indispensable to us, others are not only detrimental to the growth of vegetation, but become breeders of many of our common diseases.

In the experiments performed by my pupils to ascertain the number of microbes present in the soil, I made them adopt the method of triturating a weighed quantity of the dried sample with a measured quantity of sterilized water. Of the fluid thus prepared, 1 cubic centimeter was taken by means of a sterilized pipette, and transferred to a flask containing sterilized bouillon. In this way they found, during the summer, the following results, expressed in numbers of microbes per gram of soil:

Soil from upturned street, near the Battery, New York	1,565,000
Soil from upturned street, Park Place, New York	2,100,000
Soil from upturned street, Twenty-fifth Street and Tenth Avenue	1,830,000
Soil from upturned street, Ninety-fifth Street and Ninth Avenue, New York	842,000

As in the former experiments with the air, we did not attempt to ascertain the characteristics of each type of microbe in these soils, because to have made such an attempt would have entailed more time and labor than I could afford for successive cultivations and transplantations into various media at various temperatures, and would have necessitated the inoculation of various animals which were not at my disposal. It is, therefore, only fair to say that my figures do not necessarily imply the presence of pathogenic forms. Samples of soil may owe vast variations in the number and species of microbes they contain to minor local influences, and most of the microbes are located very near to the surface. While it is an undoubted fact that the majority of them are harmless when introduced into the human and animal body, it has been shown that the bacilli of tetanus, anthrax, typhoid fever, malaria and cholera may easily exist among them, and this gives emphasis to the point that the constant upturning of streets is detrimental to the health of the community, and that some efficient arrangement is called for whereby the upturned soil may be prevented from becoming dry and transformed into dust. Wherever we have the dust we have the microbes, and there is no form in which they are better conveyed or more readily propagated.

In accordance with the workings of a very familiar natural law, the dust-borne soil microbes are particularly dangerous in the summer-time. I refer to the law under which every process of vegetation is hastened or retarded by conditions dependent on the temperature and the moisture of the surrounding medium. It finds its limit within certain extreme degrees of temperature, and its greatest activity at a fixed mean between these extremes. The cardinal points of temperatures, as they affect the life of cells, are, therefore, distinguished as minimum, maximum and optimum. If the raising or lowering of the temperature beyond the maximum or minimum point reaches certain extreme degrees, animation is suspended or life is destroyed.

The variations that occur in all these respects are in conformity with the species, the state of development and the character of the environment.

From the experiments I have made, and from the data collected from various investigators, the non-parasitic species, if well and properly nourished, have a tolerably wide range and a high optimum of growth temperature. For the *Bacillus subtilis*, for example, it is between 42° and 122° F., the optimum being at about 86° F. For *Bacterium termo* it is between 42° and 105° F., the optimum being 85° to 95° F. For *Bacillus amylobacter* it is about 105° F., the maximum being, say, 114° F. The optimum temperature for the formation of spores in endosporous bacilli appears to approach that of growth.

The temperature of vegetation may, in the case of the majority of bacteriæ, be so lowered without destruction of life, however, that we may practically say there are no limits. I have demonstrated, over and over again, for example, that many forms are unaffected when they are frozen in a fluid at a temperature of 14° F., and afterwards thawed out. The upper death temperature, on the other hand, is the same—or nearly the same—for the majority of vegetative cells, say 125° to 155° F., although the spores of some bacilli are capable of enduring extreme high temperatures—225°, 235°, 250° F.

You will understand that I am briefly giving you examples of general rules, and that these are not affected by the exceptions which may occur in some special cases, depending in part on the species and individuals, and in part on the external conditions, such as length of time during which they are heated, dried or soaked, and the nature of the surrounding fluid.

Miquel describes a species which develops rapidly at a temperature much over 125° F., and another which, while growing and forming spores in a nutrient solution at 165° F., ceases to live when the heat is carried to 167° F. Again, Duclaux, in his studies upon the *Bacillus tyrothrix*, which he obtained from cheese, made some very interesting and important observations upon this point. He found that, cultivated in a neutral fluid, the cells were only killed at a temperature of 195° to 205° F., while the ripe spores remained capable of germination in a similar fluid when subjected to a tem-

perature of 240° F. It is a most important fact that in milk the spores of one of this species remained uninjured when heated to 250° F. The same spores immersed in gelatine were killed directly they reached 230° F.

Of all the conditions connected with the growth and development of germs, the most important is the requisite supply of water. Withdrawal of water, to the point of air-dryness, invariably and surely kills vegetative cells, such as we are accustomed to meet with in every-day life, in a very short space of time. Here again, however, the resistance of spores is greater than that of the vegetative cell; for it has been shown that *Bacillus subtilis* will withstand it for a period of three years, and that other species are still more obdurate. It has been demonstrated that oxygen is not equally necessary to the existence of all species of germs, and there are cases known where oxygen has impeded, and will even destroy, the vegetation of cells when applied under high pressure. *Bacillus anthracis*, for example, has been known to remain alive for a fortnight in oxygen under a pressure of 15 atmospheres, but was found to be dead at the end of a month; and Duclaux has proved that many air-germs, when withdrawn from the other necessary conditions to their growth, will degenerate and die more quickly under the continued effect of atmospheric oxygen than when oxygen is excluded. He gives, as an illustration of this, the fact that some glass bottles, which had been used by Pasteur in 1860, were kept hermetically sealed, and were, in fact, altogether lost sight of. At the end of twenty-five years it was found that, while the contents of the bottles were completely destroyed, the bacteriæ with which they were infested were quite alive and capable of development. Some other bottles of the same age, which had been used for experiments at the same time, had not been sealed, but had merely been plugged with cotton-wool. The plugs had been kept all the intervening years quite free from dust and quite dry, but were in full contact with the air. These did not contain a single living germ. A few similar plugs, which were only five or six years old, however, contained germs still capable of development.

Our knowledge of the most appropriate feeding media for all forms of bacteriæ or mould is very far from complete; but even if we were more advanced in this direction, there are, besides the actual food requirements, other essential chemical qualities which must be possessed by a liquid that is destined to cultivate different species. A very large number of organisms flourish best, all other conditions being the same, in a solution with a neutral or a slightly alkaline reaction. In these cases, if the reaction should become sufficiently acid, the vegetative process is at once hindered or wholly stopped. Thus, the development of *Bacillus subtilis* is impeded if one five-hundredth of sulphuric or tartaric acid or if two-tenths of lactic or butyric acid be present; and since the prejudicial acid compounds are often formed as a direct result of the vegetative process itself, the action of the microbe is very frequently stopped by the accumulation of its own products.

The branch of bacteriology to which I have given the greatest share of my own attention relates more particularly to the industries of fermentation. Its proper application to these industries is of comparatively recent date, and I think it is no exaggeration to say that its present enormous development is primarily due almost entirely to the laborious investigations of two men. The first was the late illustrious Frenchman, Louis Pasteur, and the second is the well-known Dane, Emil C. Hansen, of the Carlsberg laboratory. Until Pasteur published the results of his first experiments in 1857, little or nothing was known of the micro-organisms which we now fully recognize as playing the all-important part in fermentation as well as in many processes in the economy of nature and the arts. It is true that in 1836, Cagniard de la Tour and Schwann simultaneously discovered that, during fermentation, yeast developed new cells by budding or sprouting; but that this conveyed nothing to the minds of their scientific contemporaries is amply shown by the utterances of Liebig in 1839. This great chemist at that time promulgated the theory that when nitrogenous matter is brought into contact with oxygen, it undergoes a change of composition which disturbs

the equilibrium of the attractive forces previously binding the atoms together. This sets up an alteration of arrangement in the constituent atoms of the molecule, which causes a molecular motion to be transmitted not only through all the parts of the nitrogenous matter, but also to the molecules of such fermentable substances as may be in contact with it. The result of this motion in the sugar molecule was, according to Liebig, a rearrangement of its elementary atoms, resulting in the production of alcohol and carbonic acid gas. You will see, of course, that this does not contemplate any physiological action whatever, and will understand the revolution created by Pasteur when he demonstrated that alcoholic fermentation is a chemical action connected with the vegetable life of certain cells, and effectually proved that, providing the air is quite germless, the so-called unstable substances of the albumen type never develop organized bodies, and can never undergo either putrefaction or fermentation.

You are, of course, aware that, prior to the work of Pasteur, the great majority of scientists inclined to the theory of spontaneous generation. As a first step necessary to demolish this belief, it was necessary that all experiments should be conducted with liquids known to be free from all kinds of organized germs. It was soon discovered that this freedom is attained by submitting the liquid to be operated on to a high temperature. Different liquids were found to require different degrees of heat in order to make them sterile. For acid fluids, such as vinegar, for example, a temperature of 122° F.; for hopped wort, 158° F. to 167° F.; for unhopped wort, 194° F.; for milk, about 230° F., and some other organic liquids as high as 248° F. Sour milk requires to be heated 36° F. to 54° F. less than fresh milk, and while a temperature of 212° F. suffices for new wine, that in which the acidity has been neutralized by carbonate of lime requires a much higher degree of heat.

In order to avoid all possibility of error from this source, Pasteur boiled all the liquids he worked with, in a flask known as the Chamberland flask, with a long drawn-out neck brought to a fine point at the top. By this simple

precaution he not only secured the boiled liquid against the invasion of outside germs, but ensured the proper oxidation of the dissolved substances contained in it. The theory that oxidation of albuminous matter develops cells of yeast or other ferment was readily and finally disposed of by these means, and Pasteur soon declared that under no known circumstances can albuminous matter be transformed into yeast or any other organized ferment.

This theory being abolished, the next to be dealt with was that of the school which held that one kind of ferment was capable of developing into other varieties. This necessitated a special series of experiments, which were carried out by Pasteur with great skill and care. He avoided all the errors of his predecessors and contemporaries by operating on pure specimens of individual moulds and ferments. These he cultivated under the most varied conditions without ever succeeding in finding any evidence of the alleged transformation. As he says himself, "during the weeks and months over which my observations extended, there was not the least formation of yeast from *Penicillium glaucum*, and although I have frequently repeated this and other experiments of a similar kind, I have never detected the appearance of either ordinary yeast or any true alcoholic ferment when proper precautions were taken to secure a pure growth of the species experimented with." By the same rule "yeast cannot transform itself into any kind of bacteriæ. The cells may, and do, by certain changes in the medium, the temperature and other conditions, change their aspect and become oval, elongated, spherical and larger or smaller in size, but if the yeast be actually pure when sown in the medium, it will never produce the most minute quantity of bacteriæ or of lactic ferment or of lactic acid."

In the course of his preliminary pure culture experiments; Pasteur used flasks with two openings, which have since borne his name, and which differ somewhat from that to which I alluded a moment ago. In the most modern form the extremity of the one opening is fitted with a short piece of india rubber tubing, with its end closed by a glass stopper,

and the extremity of the other is long-drawn-out, and in the shape of a V. Access is gained to the contents of the flask by means of the short tube, either to impregnate the liquid with the ferment to be cultivated, or to remove a small portion of that which has been there produced. The finely-drawn-out end of the long tube is lightly plugged with asbestos or cotton wool. You will see that Pasteur was able not only to sterilize his liquids in these flasks, but to maintain them in a sterilized condition while allowing free access for the necessary air. The nutritive fluid which he selected as most propitious for each variety of germ was first boiled in the flask, and, after cooling, was impregnated by touching it with the end of a piece of platinum wire, bearing a very small quantity of the purest obtainable specimen of the particular ferment. The germs from the air were all rigorously excluded, and the liquid itself was sterile. It follows from this that even if the ferment introduced contained more than one kind of organisms, the predominating species or race would be in exactly the most suitable conditions for rapid development, and would crowd out the weaker or minority species. Hence, in a second growth, started from the product of the first, the impurities which may have existed with the original specimen would naturally be fewer and would finally completely disappear, leaving only the one selected race in mastery of the field.

It would be obviously impossible, even if it were not unnecessary for me to dwell at any length upon the enormous extent and variety of Pasteur's experiments, but I think it will be proper to briefly summarize the main conclusions that he drew from them in the following way:

(1) Alcoholic fermentation is a chemical action connected with the vegetable life of cells, which cells, in the absence of free oxygen, live by withdrawing the oxygen they require from certain carbohydrates, such, for example, as sugar.

(2) Only one definite class of cellular organisms are capable of decomposing sugar into alcohol and carbonic acid, and all the members of this class more or less resemble each other.

Thus you will perceive that Pasteur divided all living

germs into two classes: (1) *Ærobian*, or those which cannot live without air; and (2) *Anærobian*, or those which for a time can do without it, and he placed the alcoholic ferments in the latter class.

At this late day and in the light of all our present advantages, it is difficult for us to realize that the proofs adduced by Pasteur in support of his life theory failed to convince Liebig. That they did so fail is, however, shown by the fact that in 1869 Liebig wrote: "I had admitted that the resolutions of fermentable matter into compounds of a simpler kind must be traced to some process of decomposition taking place in the ferment, and that the action of this same ferment on the fermentable matter must continue or cease according to the prolongation or cessation of the alteration produced in the ferment. The molecular change in the sugar would, consequently, be brought about by the destruction or modification of one or more of the component parts of the ferment, and could only take place through the contact of the two substances. The idea that the decomposition of sugar during fermentation is due to the development of the cellules of the ferment is, however, in contradiction with the fact that the ferment is able to bring about the fermentation of a pure solution of sugar. Now, since the greater part of the ferment is composed of a substance that is rich in nitrogen, sulphur and phosphates, how is it possible to admit that the number of yeast cells can increase in a pure solution of sugar devoid of these elements?"

At the first blush this does not sound unreasonable; but the argument was based on a fallacy, and the way in which Pasteur met it was eminently characteristic of his practical mind. He made fresh experiments, starting with weighed quantities of ferment, and noting the weights of yeast developed by growth in pure sugar water. To prove the intimate connection between the development of ferment cells and the decomposition of sugar, he demonstrated the budding of the cells under the microscope, and showed that while *fermentation* was checked by chloroform, prussic acid, bichloride of mercury, ether, creosote, and the oils of tur-

pentine, lemon, cloves and mustard, *hydrolysis*, by the soluble albuminous bodies known as *Enzymes*, was not interfered with by any of these substances. He also showed that while yeast could not permanently reproduce itself in solutions of pure sugar only, it nevertheless carries with it enough nitrogenous and mineral matter for the immediate needs of its own life, besides providing for considerable development of new cells. He showed this in a very ingenious way by adding to a sugar solution the filtered extract from 5 grams of dead yeast, and by impregnating the mixture with only an infinitesimally small quantity of living and healthy yeast. As the result of this experiment, he found that 10 grams of the sugar contained in the solution were decomposed in nine days; whereas, in a similar sugar solution, to which he added the much larger quantity of 5 grams, by weight, of healthy yeast, 12·9 grams of sugar were decomposed in six days. He also prepared a sugar solution containing only the *ashes* of yeast and a salt of ammonia, and was able to prove beyond doubt that the yeast could live in it and increase in weight. Since this solution contained no trace of albumen, how could the argument that "a ferment consists of an albuminous substance undergoing decomposition" do otherwise than fall to the ground, never to arise? Whether Liebig was really convinced of his errors we shall never know, for he was too obstinate to publicly admit his defeat.

He contented himself, however, by owning that "from a chemical point of view, a *vital* action is a phenomenon of motion, and that, in this double sense of life, Pasteur's theory agreed with his own and was not in contradiction with it." He said: "The only co-relation between the physiological act and the phenomenon of fermentation is the production, in the living cell, of a substance which, by some special property (analogous to the action of diastase), may bring about the decomposition of sugar in other organic molecules. The physiological act in this view would be necessary for the production of this substance, but would have nothing else to do with the fermentation."

[*To be concluded.*]

NIAGARA ON TAP.*

By T. Commerford Martin.

It is a singular fact that no great work in art or literature is associated with Niagara, and that almost, if not quite, alone among the natural glories of this western world, its name does not call up at once some famous, immortal painting or poem, some distinctive piece of description or fiction. I do not say that Niagara is without minor tributes in art or song; but that no transcendent sustained effort of the intellect has hitherto been called forth by it. Our mountains, our plains, our seashore, our continental rivers, even our lonely New England farms and our isolated Louisiana bayous, have their artists of one sort or another, and have even created schools; but Niagara's emerald front is as bare of memorable inscription as that of an Alaskan seawall glacier, and her wreathing pillars of mist are never seen touched with the rainbow splendor of any enduring imagery of genius. Yet it cannot be said that the immensity of the subject has dwarfed or dulled the observer. Even the deluge once found a spirited reporter; and the newly-married couples who swarm hither at all seasons are not dismayed by its grandeur, but hear in its solemn music only a cheerful echo of the recent wedding march, to which they so blithely took a Niagara plunge into the realities of life. As a matter of fact, there have been notabilities not a few who found Niagara smaller and meaner than their dreams had depicted; some have even confessed aloud their bitter disappointment at its ridiculous inadequacy. For example, Mrs. Jamieson, a well-known English writer in her day, was sorry to have seen the Falls, preferring her imagination of them; while not long since Colonel Ingersoll objected eloquently to their crude display of mere barbaric and dangerous power. Such criticisms are offset by elo-

* A lecture delivered before the Franklin Institute, January 3, 1896.

quent utterances from Hawthorne, or Moore, or Dickens, or Margaret Fuller, that serve to eke out the scant measure of one's own vocabulary of delight and wonder; but the fact remains that Niagara is to this day well-nigh unhistoried and unsung—except in the excursion literature of the New York Central Railroad Company.

Such being the case, it will not, perhaps, seem wildly fanciful if I venture to think that hereafter the great work of genius that is to associate itself in the world's thought with Niagara is to be a piece of engineering. The mere idea will be violently reprehended by romanticists and those lovers of natural beauty who forget that their own intrusion into primeval solitudes is but part and parcel of the vulgarizing familiarity they affect to despise. For my own part, I have never been able to determine the point at which natural scenery should remain inviolable by man. It is an obvious fact that the grandeur of the setting is always more or less a pledge of the harmonization with it of the work that is to be brought into it by the ingenuity and intrepidity of the engineer. The Atlantic surely does not lose anything by contrast with the swift and stately steamer that shuttles through its storms and calms. The railroads that scale the Andes add new elements of the colossal and grandiose to the scene, as do the St. Gothard and Simplon tunnels to the overpowering magnitude of the Alps they pierce. So, too, I wish to assert that the utilization of Niagara by electricity is in no sense a belittling of its splendors or a cheapening of its charms. One is still able, without a single disturbing hint of the existence of the enterprise, to see the wild cataract leap in glory; one still awaits the coming and going of the land-locked rainbows; one may still behold white clouds born out of the sonorous conflict of rock and foam, and watch them float softly away; one still holds the breath instinctively as the ocean torrent plunges madly along the gorge; and one will still pause for many a lazy hour in the hollow of the hills where the tired waters circle slowly and slowly in malachite coils and languid ripples. Yes, we revel as of wont in all the old and unworn beauties of the scene; but we shall enjoy, and many

with us, through the years to come, a new pleasure from the engineering spectacle in which, with consummate foresight of aim, dignity of purpose and skilful adaptation of means to end, Niagara has been taught to do good as well as to be natively awful and beautiful. So far from apologizing for the presence of modern mechanism and engineering triumphs in this realm of natural masterpiece, I would urge that we have here a promise and augury of the part that electricity is to play in the larger reclamation of hitherto wasted forces of nature—a process of utilization that will give us light, heat, power and locomotion over wide areas without grime or dust, and without a smudge in the sky, so that manufacturing cities, far larger than New York, will know an air as pure and sweet and serene as though not a wheel were turning anywhere.

The broad idea of the utilization of Niagara is by no means new; for even as early as 1725, while the thick woods of pine and oak were still haunted by the stealthy redskin, a miniature saw-mill was set up amid the roaring waters, that long remained far more familiar with the savage war-cry of Iroquois or Senecas than the creak and splash of our ancestors' primitive machinery. The first systematic effort to harness Niagara was not made until nearly 150 years later, when the present hydraulic canal was dug and the mills were set up, which, like hucksters' booths around an old Italian Cathedral, disfigure the banks just below the stately Falls, their discharge of the water uneconomically used at low pressure being the only picturesque element in the scene.

It was long obvious that even an enormous extension of this surface canal system would not answer for the proper utilization of the illimitable energy contained in a vast stream of such lofty fall as that of Niagara. Let us recall what Niagara is. It is the point at which are discharged, through two narrowing precipitous channels, only 3,800 feet wide, the contents of 6,000 cubic miles of water, with a reservoir area of 90,000 square miles, draining 300,000 square miles of territory. The ordinary overspill of this Atlantic set on edge has been determined to be

equal to about 275,000 cubic-feet per second, and the quantity passing is estimated as high as 100,000,000 tons of water per hour.

The drifting of a ship over the Horseshoe Fall has proved it to have a thickness at the center of the crescent of over 16 feet. Between Lake Erie and Lake Ontario there is a total difference of level of 300 feet, and the amount of power represented by the water falling within that distance has been estimated on different bases from 6,750,000 horse-power up to not less than 16,800,000 horse-power, the latter being a rough calculation of Sir William Siemens, who, in 1877, was the first to suggest the use of electricity as the modern and feasible agent of converting into useful power some of this majestic but squandered energy.

It was Mr. Thomas Evershed, a civil engineer of appropriate name, who unfolded the plan of diverting part of the stream at a considerable distance above the Falls, so that no natural beauty would be interfered with, while an enormous amount of power would be obtained with a very slight reduction in the volume of the stream at the crest of the Falls. Essentially scientific and correct as the plan now shows itself to be, it found prompt criticism and condemnation, but not less quickly did it rally the able and influential support of Messrs. W. B. Rankine, Francis Lynde Stetson, Edward A. Wickes and Edward D. Adams, who organized the corporate interests that, with an expenditure of $5,000,000 in five years, have carried out the noble work which it affords me pleasure to bring to your notice this evening. The evolution of the plans and the execution of the work constitute a great many separate chapters of history, but we shall only be able to find time for the salient features and the concrete results.

So many engineering problems arose early in the enterprise, that, after the survey of the property in 1890, an International Niagara Commission was established in London, with power to investigate the best existing methods of power development and transmission, and to select from among them, as well as to award prizes of an aggregate

$22,000. This body included men like Lord Kelvin, Mascart, Coleman Sellers, Turrettini and Prof. Unwin, and its work was of the utmost value. Besides this, the Niagara Power Company and the allied Cataract Construction Company enjoyed the direct aid of other experts in a consultative capacity, while it was a necessary consequence that the manufacturers of the apparatus to be used threw upon their work the highest inventive and constructive talent that they could possibly employ. It was a not less necessary consequence that there should be and will be controversy as to the origin of this or that conception incorporated in the details adopted, and an equally earnest disclaimer as to the things discarded. I suppose this must always be so. One comes, indeed, to question the importance or validity of any new idea or achievement that has not a dozen claimants and a score of infringers.

The final plan adopted will now be referred to, although I may first contrast it with an amusing one in which the promoter intended to use what I may call outdoor wheel pits, or funnels stuck up immediately under the flow of the water, debris, rocks and rolling tree trunks of the Falls. This ingenious plan was seriously entered for the prize of $100,000 offered by Buffalo for the best plan of utilizing Niagara, but you will agree with me that the perfected and concentrated Evershed scheme is the better of the two. It comprises a short surface canal, 250 feet wide at its mouth, 1¼ miles above the Falls, far beyond the outlying Three Sisters Islands, with an intake inclined obliquely to the Niagara River. This canal extends inwardly 1,700 feet, and has an average depth of some 12 feet, thus holding water adequate to the development of about 100,000 horse-power. The mouth of the canal is 600 feet from the shore line proper, and considerable preliminary work was necessary in its protection and excavation. The bed is now of clay and the side walls are of solid masonry, 17 feet high, 8 feet at the base and 3 feet at the top. The northeastern side of the canal is occupied by a power-house and is pierced by ten inlets, guarded by sentinel gates, each being the separate entrance to a wheel pit in the power-house, where the water is used

and the power is secured. The water, as fast as used, is carried off by a tunnel to the Niagara River again.

Just here I may point out one of the material differences in the general Evershed Niagara plan made by the adoption of electricity. At first it had been deemed natural to plant individual factories widely apart along such a canal, each developing its own power for itself and using a tunnel as a common raceway recipient for the water used. But with

electricity it at once became easier and better to develop and generate all the power wholesale in one spot and then distribute it electrically to the various factories needing it. This released the factories from a narrow choice of sites, gave freedom of location for various industries, concentrated the work of power generation, lessened the expense and enabled each mill-owner to take just the power that he needed at the moment and no more. We detect here one of the greatest virtues of electrical transmission of power.

The old-fashioned water-mill or factory has had to get right down in the hot, dark valley, and gather there, under insanitary conditions, its human forces. The new electric factory lifts itself to the heights and in free air and sunshine, in defiance of all ancient saws and proverbs to the contrary notwithstanding, grinds away cheerfully with the water that may have rushed by its door half an hour ago.

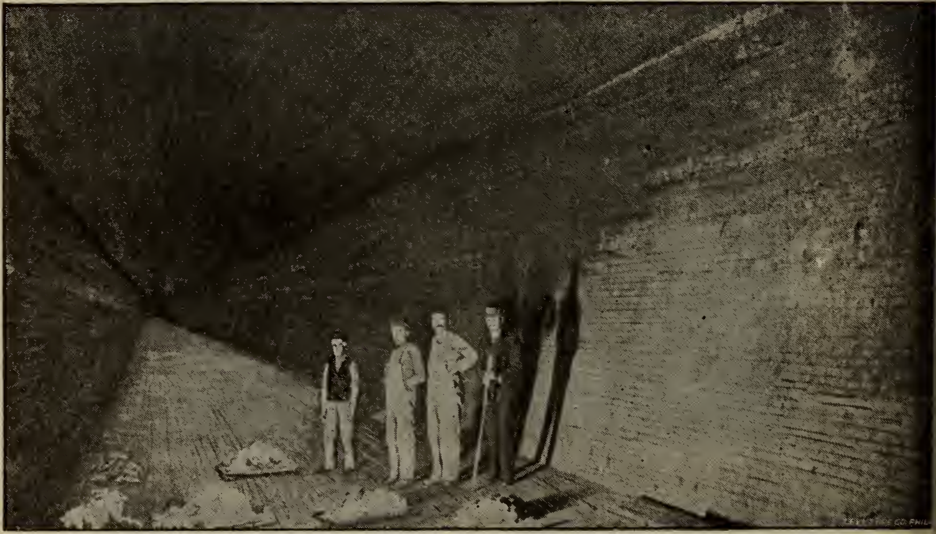
The massive canal power-house, of whose machinery we shall have more to say in detail further on, is a handsome building, designed by Stanford White, and likely to stand at least until Niagara, spendthrift fashion, has consumed its way backward through its own crumbling strata of shale

View of power-house from canal.

and limestone to the base of it. This building is outwardly of hard limestone and inwardly of enamel brick and ordinary brick coated with white enamel paint. It is 200 feet in length at present, and has a 50-ton Sellers electric traveling crane for the placing of machinery and the handling of any parts that need repair.* The wheel-pit, over which the power-house is situated, is, in reality, a long, deep, cavernous slot, at one side under the floor, cut in the rock, parallel with the canal outside. Here the water gets a fall of about 140 feet before it smites the turbines; and after delivering up its energy

* Since this lecture was delivered, the extension of the power-house has been begun, being rendered necessary by the contract for current in Buffalo.

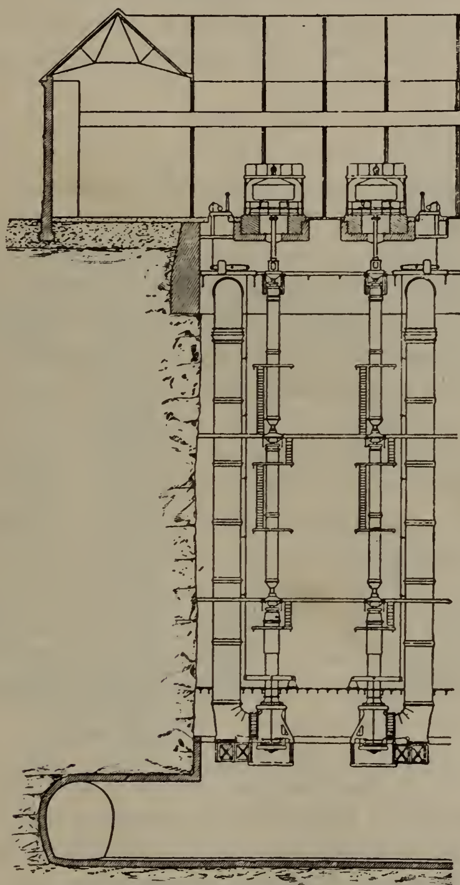
generously to these, like Santa Claus coming down the chimney with Christmas gifts, it runs off and disappears into the tunnel raceway. The arrangement of the dynamos generating the current up in the power-house is such that each of them may be regarded as the screw at the end of a long shaft, just as we might see it if we stood an ocean steamer on its nose with its heel in the air. At the lower end of the dynamo shaft is the turbine in the wheel-pit bottom, just as in the case of the steamer shaft we find attached to it the big triple or quadruple expansion marine



View in the great tunnel.

steam-engine. Perhaps we might compare the dynamo and the turbine to two reels stuck one at each end of a long lead-pencil, so that when the lower reel is turned the upper reel must turn also. You might also compare the dynamos to bells up in the old church steeple, and the turbines to the ringers in the porch playing the chimes and triple bob majors by their work on the long ropes that hang down. The turbines in the Niagara power-house receive their water-supply from the canal through the huge penstocks or intake pipes; but after the water has done its lofty tumbling act of

140 feet and passed through the turbines, it has to get away, and this is the reason for the huge waste-water tunnel or tail raceway. The wheel-pit which contains the turbines is 178 feet in depth, and connects by a lateral tunnel with the tunnel running practically at right angles.



Wheel-pit, showing power-house and tunnel.

This main tunnel is no less than 7,000 feet in length, with an average hydraulic slope of 6 feet in 1,000. It has a maximum height of 21 feet and a width of 18 feet 10 inches, its net section being 386 square feet. It is as capacious as any of the Paris sewers that Victor Hugo

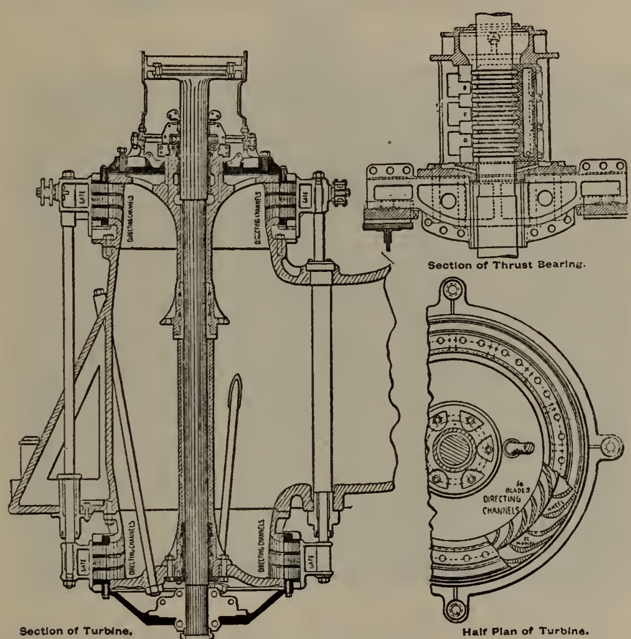
wrote about. The water rushes through it and out of its mouth of stone and iron at a velocity of 26½ feet per second, or nearly 20 miles an hour. Evidently there is quite a little energy left in the stream when it emerges at the Suspension Bridge and hastens to explain in a subdued way to the other main stream that has shot the chute in the old conservative way, why it has come more quietly and usefully down the back stairs, like a domestic in some fashionable New York flat.

More than 1,000 men were employed continuously for more than three years in the construction of the tunnel. More than 300,000 tons of rock were removed, which have gone to form part of the new foreshore near the powerhouse. More than 16,000,000 bricks were used for the lining, to say nothing of the cement, concrete and cut stone. The labor was chiefly Italian, and the dago did his work just as well as when, centuries ago, he built the aqueduct across the Roman Campagna and laid the wonderful roads in England and Europe that some of us have played on as boys. Of course, there were accidents, as there always will be with humanity in the bulk and careless, but I like to recall one pathetic story. It appears that when the rock was being excavated and the buckets were being raised and lowered, the Italians at the top would shout to those below underground to stand out of the way so that they might not get hit. One day an Italian up on top lost his footing, but as he fell he shouted out to those below the old familiar warning, so that they might not be smashed by his descending body. I do not know where they buried that dago, but I know that in his obscure grave there lies a hero.

Some idea of the rush of the stream through that dark tunnel may be gathered from the fact that a wooden chip thrown in at the canal wheel-pit passes out at the Suspension Bridge portal in 3½ minutes, which is five times as fast as you or I can walk. The brick that fences in that headlong torrent consists of four rings of the best hand-burned brick, of special shape, making a solid brick wall 16 inches thick. In some places it is thicker than that. Into this tunnel discharges also, by a special sub-tunnel, the used-up

water from the water-wheels of the Niagara Falls Paper Company.

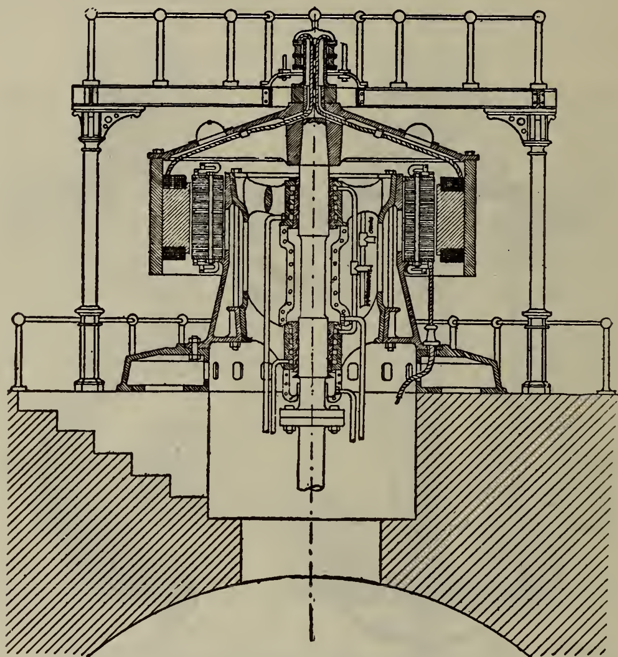
We must come back again to the stately power-house, on the bank of the intake canal, and see what kind of machinery it has been filled with; but before studying the dynamos it will be natural and proper to glance at the turbines that drive them in the way I have just alluded to. These wheels have to generate 5,000 horse-power each, at a distance of 140 feet underground, and to send it up to the sur-



Vertical and horizontal sections of the 5,000 horse-power turbines.

face. For this purpose the water is brought down, as I have already said, by a supply penstock, big as a bowling-alley, made of steel tube and 7½ feet in diameter. This water strikes what is essentially a twin wheel, each receiving part of the stream as it rushes in, the arrangement being such that each wheel is three stories high, the water under the upper half serving as a cushion to sustain the weight of the entire revolving mechanism. These wheels will discharge 430 cubic feet per second, and they make 250

revolutions per minute. At only 75 per cent. efficiency they give 5,000 horse-power. The shaft that runs up from each one to the dynamo is of peculiar and interesting construction. It is composed of steel, ¾ of an inch thick, rolled into tubes which are 38 inches in diameter. At several intervals, as you see, this tube passes through journal bearings or guides that steady it, at which the shaft is narrowed to 11 inches in diameter and solid, flaring out again

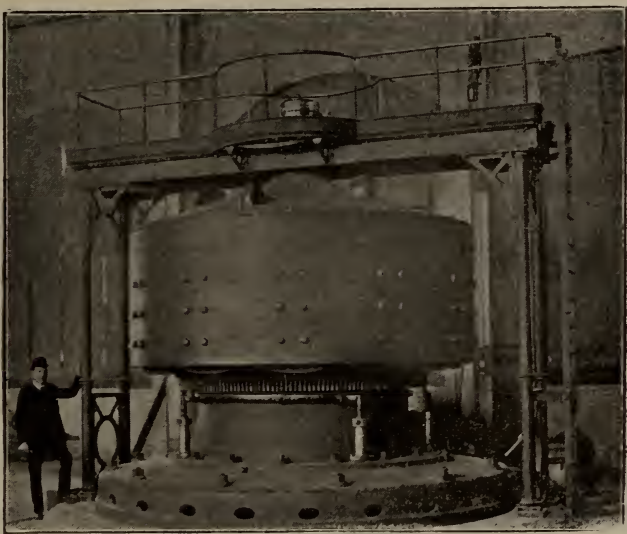


Section of 5,000 horse-power two-phase alternator.

each side of the journal bearings. The speed gates of the turbine wheels are plain circular rims, which throttle the discharge on the outside of the wheels, and which, with the co-operation of the governors, keep the speed constant within 2 per cent. under ordinary conditions of running. These wheels are of the Swiss design of Faesch & Picard, and have been built by I. P. Morris & Co., of Philadelphia, for this work.

The big dynamos must now receive our attention. They

are of the Tesla two-phase type, the principle embodied in them being a radical departure in dynamo electric machinery, and one of the many striking innovations and improvements that electricity owes to Mr. Nikola Tesla. At first, when electricity was proposed as the means of transmiting this energy, the direct continuous current was advocated, and even insisted on, by men so world-famous as Lord Kelvin. But it was found that the continuous form of current, useful as it is, would not answer, and then choice settled upon the alternating current, which could be sent over the fine wires



5,000 horse-power two-phase alternator.

at a high voltage or potential, and be reduced in pressure or otherwise converted at the various points of utilization. But even the alternating current in its simple form is not all that is needed, and hence, after everything had been carefully estimated, weighed and discussed, Mr. Tesla's idea as to the superiority of a two-phase current was adopted, and the apparatus was built on that plan by the Westinghouse Company, as the best to meet all the exacting requirements of the great enterprise. In popular language, it might be said that each of these dynamos, not

unlike the turbines, consists of two working interlocked together. In technical language it may be stated that each of these dynamos produces two alternating currents, differing 90° in phase from each other, each current being of 775 ampères and 2,250 volts, and the two currents added together making in round figures very nearly 5,000 horse-power. This amount of energy in electrical current is delivered to the circuits for use when the dynamo is run by the turbine at the moderate speed of 250 revolutions per minute, or say four revolutions a second. Here then we have broadly a Tesla two-phase generator, but of course it embodies the novel suggestions and useful ideas of many able men, among whom should be specially mentioned Mr. L. B. Stillwell, the gifted young engineer of the Westinghouse Company, upon whom vast responsibility has been thrown, and Prof. George Forbes, of England.

Each generator from the bottom of the bed-plate to the floor of the bridge above it is 11 feet 6 inches high, and the whole machine could be stood inside a room only 15 feet high and 15 feet square. One is really disappointed at seeing it, for you expect your money's worth in a machine that is to deliver 5,000 horse-power of electrical energy, and which receives only 5,150 mechanical horse-power in order to be able to do so. Each generator weighs 170,000 pounds, or 85 tons, and the revolving part alone weighs 79,000 pounds, or nearly 40 tons. In most dynamos, the armature is the revolving part, but in this case it is the field that revolves, while the armature stands still. It reminds you of the figure in dancing where the ladies stand in the centre and the gentlemen circle graciously around them. The revolving field is for all the world like a huge Chinese Mandarin's umbrella, the turbine and shaft being the clubbed handle and stem while the driver or span-piece at the top is the frame, and the field magnet jacketing all around is the silk covering with its fringe. It is noteworthy that if the armature inside the field were to revolve in the usual manner instead of the field, its magnetic pull would be added to the centrifugal force in acting to disrupt the revolving mass, but as it is, the magnetic attraction toward

the armature now acts against the centrifugal force exerted on the field and thus reduces the strains in the huge ring of spinning metal. The stationary armature inside this field is built up of thin sheets of mild steel, laid one on top of the other, as though they were a Brobdignagian pile of buckwheat cakes. Along the edges of these sheets are 187 rectangular notches or juvenile tooth-marks in the cakes, to receive the armature winding in which the current is generated as the field coils fly by. This winding is in reality not a winding, as it consists of solid copper bars $1\frac{11}{32}$ by $\frac{7}{16}$ inch and there are two of these bars in every square hole, packed in with mica as a heat-resisting insulation. These copper conductors are bolted and soldered to V-shaped copper connectors, and are then grouped so as to form two separate, independent circuits. A pair of stout insulated cables connect each circuit with the power-house switchboard.

The rotating field magnet, or umbrella shade fringe, outside this armature, consists of a huge forged steel ring, made from a solid ingot of fluid compressed steel, 54 inches in diameter, which was brought to a forging heat and then expanded on a mandril, under a 14,000-ton hydraulic press, to the ring 11 feet $7\frac{1}{8}$ inches in diameter. On the inside of this ring are bolted twelve inwardly projecting pole pieces of mild open-hearth steel, and the winding around each of these consists of rectangular copper bars encased in two brass boxes. Each pole piece with its bobbin weighs about $1\frac{1}{4}$ tons, and the speed of this mass of steel, copper and brass is 9,300 feet, or $1\frac{3}{4}$ miles per minute, when the apparatus is running at its normal 250 revolutions. Not until the ring was speeded up to 800 revolutions, or 6 miles per minute, would it fly asunder under the impulse of centrifugal force. As a matter of fact, 400 revolutions is the highest speed that can be attained, so that it is hardly likely that the attendants in this power-house will ever have to dodge stray chunks of broken flywheel as do those sometimes who work in big steam plants, although, as will be seen, the revolving field is nothing more than a big flywheel running in a horizontal instead of a vertical plane.

Let us see how this revolving field magnet is connected with the shaft that has to turn it. It is supported from above by a six-armed cast-steel spider, keyed to the shaft, this spider or driver forming a roof or penthouse over the whole machine. The shaft itself is held in two bearings inside the castings, around which the armature is built up. This shaft, at the bearings, is nearly 13 inches in diameter. At the lower end is a flange, fitting with the flange at the top of the turbine shaft, and at the upper end is a taper over which the driver fits. The driver and shaft have a deep keyway, and into this a long and massive key fits, holding them solidly together. The driver is of mild cast steel, having a tensile strength of 74,700 pounds per square inch. The bushings of the bearings are of bronze, with zigzag grooves, in which oil under pressure is in constant circulation. Grooves are also cut in the hub of each spider to permit the circulation of water to cool the bearings, this water coming direct from the city mains at a pressure of 60 pounds to the square inch. The oil returns to a reservoir and is used over and over again.

It will have been noticed that there is plenty of provision against undue heating and plenty of chance for air to circulate. This is necessary, as about 100 horse-power of current is going into heat, due to the magnetization of the iron and the resistance in the conductors themselves. But I may draw your attention to the ventilators or gills in the driver, which are so arranged as to draw up air from the base of the machine and eject it at considerable velocity, so that whatever heat is unavoidably engendered is rapidly dissipated.

[*To be concluded.*]

ELECTRICAL SECTION.

Stated Meeting, September 22, 1896.

MR. CLAYTON W. PIKE, President, in the chair.

A NEW SYSTEM OF SERIES ARC LIGHTING.

BY THOMAS SPENCER.

Any one who has watched the development of arc lighting within recent years cannot have failed to notice the gradual, but radical, changes that have taken place in the methods of delivering light from a central station. Originally the idea seems to have been to break up the source of current supply into a great number of small units. Whether, from an engineering standpoint, this idea was a well-worked-out scheme, or simply the outgrowth of circumstances, is, I think, very easy to answer; for it is usual to begin on as small a scale as possible, so that, in case of failure, the financial loss will be as small as possible. These first attempts proving successful, the conservative feeling, which to a great extent accompanies the investment of money, caused a continuance in the course which had been found practical.

Perhaps in no branch of the electrical industry is this so apparent as in that of arc lighting. However, at present there seems to be a general tendency towards a more economical system, as is attested by the number of large arc light dynamos that are now replacing the numerous small machines; further, by the rapid rise of arc lighting from constant potential D. C. circuits, and also by the general interest manifested in alternating arc lighting. The last named, which, of course, signifies the use of constant potential, is the direction towards which everything seems to be tending, and will be the system most generally employed in the future, unless some efficient method of directly converting heat into electricity is discovered.

There is no question but that a station equipped with large units and supplying one kind of current—and that a

current which can most easily be controlled—is the most efficient. Such is the alternating current. As far as the alternating arc lamp is concerned, it has some points which make it slightly inferior to the direct-current lamp; but experience has shown that these objections are not so serious as at first appeared.

Recently, attempts have been made to use a device by means of which the current is commutated into a fluctuating current, having always one direction, but not with conspicuous success. There are several such plants in England, I believe, and, from some of the criticisms, I should judge that the system is by no means as efficient as it should be to be generally introduced, especially in this country, where, I am sorry to say, a piece of apparatus is apt to fall into the hands of men who fail to give it even the most necessary care. As for the advantages gained by the use of such a device, there is no doubt but that the efficiency of the arc is improved. From my experience I should judge that, as the current is a fluctuating one, the arc would still be noisy, although less so than the unrectified alternating current.

As I have said before, the objections to the alternating arc have not proved to be as serious as they at first appeared. There is a growing tendency towards the use of the alternating arc for all kinds of lighting, and this is especially marked in street lighting. The system which, up to the present time, has been in use may be described as follows: Each lamp is burned separately from a 30- or 33-volt transformer (see *Fig. 1*). The amount of wire used in this system is not generally greater, and often less, than that required in the old direct-current series system. This system works very well and has many good features, perhaps the greatest of which are that each lamp is independent of the rest, and that the pressure on the lamp is low. Furthermore, the lamp has only one series spool of coarse wire, and is free from shunt spools and cut-outs.

There are a great many systems of this sort operating in this country, and some, I believe, have been introduced in England. The only objection to this plan is its high

first cost, occasioned by the necessity of a separate transformer with each lamp. To overcome this objection and at the same time be in position to use the same kind of lamp, Mr. William Smith Horry has devised what he calls his "Reactive System" of arc lighting, which I wish to bring before you this evening. Mr. Horry couples his lamps in series directly in the primary circuit, doing away with the separate transformers. Now, any one who has attempted to run arc lamps in series, which regulate only by variations in current (that is, have only a series spool), knows very well that they will not operate. The reason for this is readily apparent. An arc lamp should depend for its regulation on

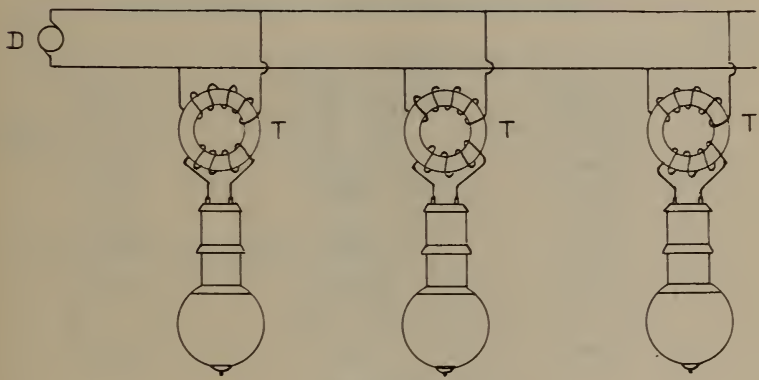


Fig. 1.

something practically affected only by the burning of its own arc. This is evidently not the case with the current where lamps are put in series across a constant potential circuit. In general, when lamps are run in series, we must regulate by the change of E.M.F. around the arc; that is, regulate with a shunt spool. A lamp, of course, similar to the regular series arc lamp, might be used if it were provided with some device to keep the current constant, or a lamp similar to that used on street railway circuits could be devised, but in all of these cases we would have a much more complicated lamp than that used by Mr. Horry.

The principle governing Mr. Horry's system is briefly this:

In shunt with each lamp is placed a small coil of the type known as auto-transformer (*Fig. 2*). The coil A is in series with the lamp, and B in shunt. With this device the current in the lamp will always be greater than that in the line. Considering the current in the line as constant, which is practically the case where a large number of lamps are in series, we must, as shown above, by some means outside of the lamp itself, cause a change in the current passing through the series spool of the lamp, in order to enable the lamp to feed. This is accomplished by making the amount of iron in the coil small, so that it will soon become saturated and cause the coil to leak, lowering the pressure,

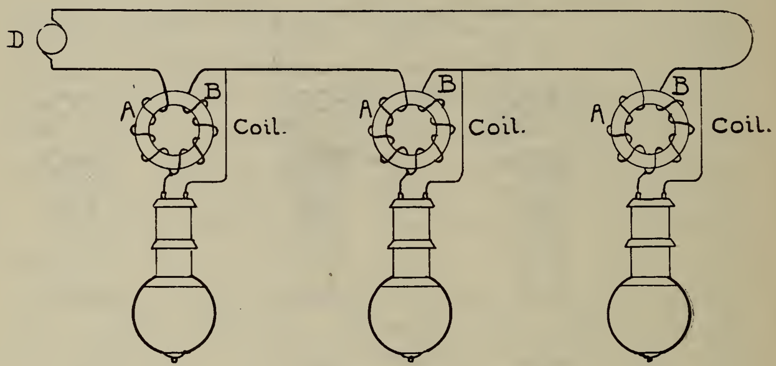


Fig. 2.

which in turn decreases the current and feeds the lamp. This can be more easily understood in the following way: The relation

$$N_1^2\, I_1^2 = N_2^2\, I_2^2 + \left(\frac{l\, B}{4\, \pi\, \mu\, a}\right)^2$$

in a transformer, where there is no leakage between the primary and secondary, is well known. (Fleming, Alternating Current Transformer, Vol. 1, p. 273.) Here N_1 and I_1 are respectively the number of primary turns and the maximum current, and N_2 and I_2 represent the same for the secondary, B the maximum induction, μ the equivalent permeability, l the length of the magnetic circuit, and a its section.

Now the secondary E.M.F. is directly proportional to B, or $B = Ky$, where y is the secondary E.M.F and K a constant. If in the first equation we write x for I_2 and substitute the value of B we have

$$N_1^2\, I_1^2 = N_2^2\, x^2 + \left(\frac{l\, K\, y}{4\, \pi\, \mu\, a}\right)^2$$

$$\therefore 1 = \frac{x^2}{\left(\frac{N_1\, I_1}{N_2}\right)^2} + \frac{y^2}{\left[\frac{\frac{4\, \pi\, N_1\, I_1}{K}}{\frac{l}{\mu\, a}}\right]^2}$$

Now, if we suppose I_1 constant, and write

$$a = \frac{N_1\, I_1}{N_2}$$

and

$$b = \frac{4\, \pi\, N_1\, I_1}{K}$$

a and b being constants, we have

$$1 = \frac{x^2}{a^2} + \frac{y^2}{\left[\frac{b}{\frac{l}{\mu\, a}}\right]^2}$$

This is easily recognized as the equation of an ellipse. Plotting this (*Fig. 3*), it is plain that, when the current is small, the E.M.F. varies very little with an increase of current; that is, it behaves in this region as a constant potential circuit. Referring again to our last equation, we see that when

$$\frac{l}{\mu\, s}$$

becomes greater, that is, when the equivalent magnetic resistance becomes greater, the minor axis of the ellipse becomes smaller. This is accomplished, as before stated, by diminishing the amount of iron in the core of the coil, and, as a result, we will have a coil whose characteristic is an ellipse,

as represented by the dotted lines. In this case the maximum E.M.F. will not be so large; but, as the ellipse is nearly flat, there is a large region over which the coil produces practically constant potential.

There are a few other features in this system worthy of mention. The coil is so proportioned that when the carbons are consumed, and the arc in consequence breaks, the whole current is forced through that portion in shunt with the lamp. The choking effect in the coil is about the same as the E.M.F. taken by the lamp when burning; in fact, it is so close to this that 30 per cent. of all the lamps in circuit may

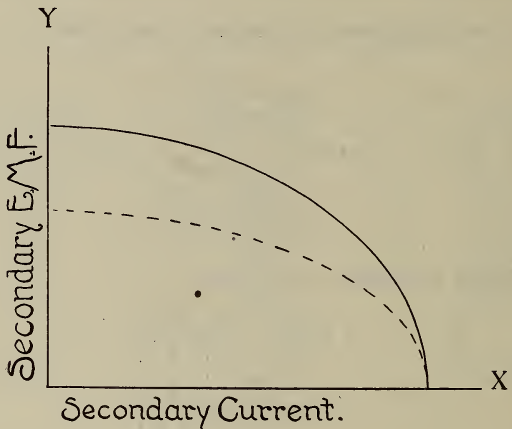


Fig. 3.

be put out without sensibly affecting the ampèremeter in the circuit. The coil then not only acts as a cut-out, but also as a regulator.

The advantage which this system shares with that in which lamps are run from separate transformers, is that it is possible to run lamps of widely different candle-power on the same circuit, which is accomplished by changing the coil to conform with the lamp. In this particular, of course, it is an improvement over the ordinary series system, with shunt coil regulation. The number of lamps which it is possible to run in series from a 1,000-volt circuit or trans-

former depends upon the candle-power of the lamps. The coils, as now constructed, will, in this case, take care of twenty-nine 2,000 candle-power lamps. Mr. Horry has also devised a switch-board to be worked in connection with a special transformer in such a way as to give varying primary E.M.F.'s, so that any number of lamps can be run in series within reasonable limits.

As for the practical working of this system, I would say that it is in use in several places in this country. As far as I know, it has been very satisfactory, and there is little doubt that a great future awaits it.

CHEMICAL SECTION.

Stated Meeting, held September 15, 1896.

DR. H. F. KELLER, President, in the Chair.

ON A NEW PROCESS FOR THE MANUFACTURE OF WHITE LEAD.

BY MR. WM. TATHAM,
Member of the Institute.

The process I am about to describe is the joint invention of Wm. P. Tatham, of this city, and myself. Before going into details, I should like to give a very brief *résumé* of what has been done heretofore.

The oldest method of making white lead, commonly termed the Dutch process, is based upon the fact that, if metallic lead be exposed to a heated atmosphere of water vapor, carbonic acid, acetic acid vapor and oxygen, it is converted into a basic lead carbonate. These conditions are obtained, as is well known, by placing pieces of lead, of convenient size, in earthen pots containing a small quantity of acetic acid, and packing these pots in a bed of spent tan or horse manure. The fermentation of the tan, or manure, generates carbonic acid and water vapor, while the heat liberated by the process of fermentation causes the acetic acid to vaporize, and the lead is thereby corroded.

The accepted theory of the process is that the lead is first converted into lead hydrate by the water vapor and oxygen present, and then into a basic acetate by the acetic acid vapor; and, in turn, this latter is driven out by the carbonic acid, and the basic carbonate of lead, or the white lead of commerce, is formed.

There are some objections to this theory; in fact, no one really knows exactly what takes place, but the ultimate result is that basic carbonate is obtained.

One objection to this process is that the quality of the product is somewhat uncertain. An expert, formerly connected with one of the largest and most successful corroding firms of this country, informs me that, after the corroding stacks or beds are put up, the corroder has no power to influence the result; it is largely a matter of temperature and circumstances.

Another objection is the amount of time consumed in corroding the lead. From the time that the lead is put into the beds, about three months must elapse before it is thoroughly corroded. Notwithstanding all this, however, the result in the long run is so successful that the product of the Dutch process is the standard of excellence for white lead; that is to say, if any one should invent a new process, the first thing he would be compelled to do would be to submit his product to a comparison with the product of the Dutch process, and if it were not equal to that, his method would be condemned.

The fact that this process is not perfect is proven by the numerous attempts which have been made to improve it. I think I am not over-stating the facts when I say that the records of the patent office, both in this country and in England, will show that hundreds of new methods have been patented.

These attempted improvements may be divided into two classes:

(1) Those in which metallic lead is corroded.

(2) Those in which the lead is first oxidized into litharge, and then attacked by acetic acid or acetate of lead.

In connection with the first class I may mention the German method, formerly practised in Carinthia, in which sheets of lead were exposed in wooden boxes to the action of corroding vapors. In this country, finely divided lead has been exposed to the action of corroding vapors while being agitated in revolving cylinders. This latter process has given very good results; but it is open to the objection that, in the revolving cylinder, the white lead formed agglomerates into little balls. Any metallic lead enclosed in these balls is protected from the action of the corroding vapors, and, consequently, the white lead formed may contain metallic lead.

The object of all the inventions in this class is to supply as many points of contact as possible between the lead and the corroding vapors. Some of them have been moderately successful.

Where litharge is used, the process is generally one of solution and precipitation—a method invented by Thènard, and commonly known as the Clichy process. This is based upon the fact that, if litharge be digested in a solution of normal acetate of lead, a sub-acetate is formed, which, if exposed to the action of carbonic acid gas, is decomposed. The basic equivalents are thrown down as a carbonate of lead, while the normal acetate remains in solution, and may be used to attack a second portion of litharge.

The objection to this process is that the product lacks the covering property technically known as *body*, which distinguishes the product of the Dutch method. It was formerly considered that this was due to the fact that the precipitated carbonate of lead was crystalline, while the lead corroded by the Dutch process was amorphous. While this may be true, it is also fairly well settled that the covering quality of white lead is largely due to the presence in the carbonate of a certain amount of hydrated oxide of lead; that is to say, the white lead of commerce is a basic carbonate.

A great many modifications of the Clichy process have been invented. They all depend, however, on the same principle, and their differences are simply differences of method of handling—simply differences of detail.

The most successful precipitation method with which I am acquainted is the one patented by Bradley. The Bradley process consists in subjecting a solution of basic acetate of lead, containing about 11 per cent. basic acetate, to the action of carbonic acid at a temperature of about 120° F., by letting the solution flow over shelves in thin sheets, so as to expose as much surface of liquid as possible to the action of the acid. The essential part of the process, however. consists in stopping it when about one-half of the basic lead oxide has been converted into white lead.

Bradley claims, in his patent, that the white lead produced in this manner contains as high as 30 to 37 per cent. of hydrated lead oxide, and is amorphous.

There is nothing new in Bradley's claim of stopping the conversion into white lead when about one-half of the basic lead oxide had been so converted. The same idea was utilized several years ago in Germany.* The novelty of his invention lies in exposing the solution in thin sheets to the action of the acid. This is not essential, as I have obtained the same results by passing a current of carbonic acid gas through a solution of basic acetate, as he directs.

The objection to the Bradley process lies in the fact that, to produce a given amount of white lead, it is necessary to keep double the equivalent amount of lead oxide in solution all the time.

The white lead produced by the Bradley method has a very good body, and its chemical composition is such as to justify him in claiming that it would make a very good paint.

It has also been proposed to mix a small portion of acetic acid with litharge and expose the mixture to an atmosphere of oxygen, steam and carbonic acid gas. The product thus obtained makes a very superior quality of white lead, but the objection to this method is the same that applies to the method of corroding the finely divided lead in revolving cylinders; that is, some of the litharge may not be acted upon, and would contaminate the product.

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* I regret to say I cannot give my authority.

The process which I am about to describe is based upon the fact that, if finely divided litharge be stirred into a solution of normal acetate of lead, in the proper proportions and at the proper temperature, the mixture *crystallizes.*

If we expose these crystals to the action of carbonic acid gas, we obtain a basic carbonate of lead, together with normal acetate of lead in solution. The basic carbonate so obtained is similar in composition to that produced by the Dutch process, and is amorphous.

The method of operation may be briefly described as follows: We will take, for example, a solution which marks about $15\frac{1}{2}°$ B., and contains about 14 per cent. of normal acetate of lead, which is equivalent to say 7 pounds of oxide of lead to the cubic foot of solution. In order to form the crystalline compound above named, therefore, it is necessary to mix with it an amount of litharge corresponding to 14 pounds of litharge to the cubic foot of solution employed.

We have found that it is possible to saturate partially the solution of normal acetate, by digesting unground litharge in it, and then to supply the final amount necessary to make the tri-basic acetate in the form of very finely ground litharge. As it is necessary to use litharge which has been passed through a bolting-cloth of about 200 meshes to the linear inch, it is advisable to saturate the solution with the coarse litharge to an extent such as will require the addition of a comparatively small proportion of fine litharge to complete the operation.

The partially saturated acetate solution is run into a copper vessel, with a double bottom or steam jacket, and provided with a stirring apparatus consisting of revolving arms. It is heated to about 140° F.; the revolving arms are set in motion, and the ground litharge is added. In from five to ten minutes the mixture crystallizes into a curdy mass. This mass is then exposed in the same vessel to the action of carbonic acid gas. The crystals melt in proportion to the conversion into white lead. The white lead formed is transferred to a filter-press, in which it is separated from the solution of normal acetate, and the latter

is used again for a fresh supply of litharge, thus making the process a continuous one.

The process is readily controlled. With a given solution of normal acetate, it is simply necessary to weigh out and incorporate therein the requisite amount of litharge, in case the whole amount is added in the form of a fine powder. Where the solution is partially saturated by the use of coarse litharge, the process must be controlled by sampling the partially saturated solution, and determining the amount of lead oxide therein contained.

The white lead produced by this process has the same composition as that produced by the Dutch method. It may be interesting to compare the analysis of the white lead produced by the Clichy method, the Bradley method, the method I am describing, and the Dutch method.

The lead produced by the Dutch process has the general formula $2PbO, CO_2, PbH_2O_2$; that is to say, it contains two equivalents of carbonate of lead and one equivalent of hydrated lead oxide. The lead produced by our method has the same approximate formula. The lead produced by the Bradley method also is very near the typical formula of good white lead. The lead produced by the Clichy method is almost a pure carbonate of lead. It contains a very small amount of hydrated oxide.

The following analyses give the approximate composition of the product of these different methods:

	Per Cent.		
	PbO	CO_2	H_2O
Thènard lead, made by the Clichy process, .	83·42	15·76	0·59
Lead made by the Bradley process	86·16	11·93	1·81
Lead made by the Tatham process	86·33	11·34	2·15

The following are analyses of white lead produced by the Dutch method, in England and Germany, respectively, taken from Wagner's Chemical Technology:

	Per Cent.		
	PbO	CO_2	H_2O
English white lead	86·51	11·30	2.23
German white lead	86·40	11·53	2·13
White lead having the formula $2PbCO_3$, H_2PbO_2, would have the composition . . .	86·32	11·35	2·32

CORRESPONDENCE.

WORTHINGTON COOLING TOWER.

PHILADELPHIA, September 2, 1896.

The Editor Journal of the Franklin Institute.

DEAR SIR:—On reading in the June number of the *Journal* an article on the Worthington Cooling Tower, I was reminded of a device used by me for the same purpose while erecting the machinery in a flour-mill at Hamburg in 1862.

The engine was a Woolf beam engine (cylinders 24 and 45 inches diameter), and the discharge from the air-pump was carried to the roof of the boiler-house (a low structure, adjoining the mill), over which the condensing water ran, passing over a number of ridges formed on the roof (which was of tin), and then falling into a well, from which it was again taken for injection into the condenser. In this manner the condensing water was sufficiently cooled to give a vacuum of 24 to 25 inches in winter and 22 to 23 inches in summer.

Hoping this may be of interest, I remain,

Yours truly, JOHN HAUG.

206 WALNUT PLACE.

NOTES AND COMMENTS.*

PENNSYLVANIA'S TIN-PLATE INDUSTRY.

Pennsylvania turned out a total product of 104,375,366 pounds of finished tin- and terne-plate for the year ending December 31, 1895, with an aggregate value of $4,237,819.42, or an average value of $81.20 per net ton. Add to the $1,161,424.58 paid out in wages by the 10 tin-plate works manufacturing black-plate, the $188,224.32 paid out in wages by the 17 dipping works, and the result is $1,349,648.90 paid out in Pennsylvania for labor in the manufacture of tin-plate during 1895. That is to say, the 2,574 persons employed by the black-plate makers, and the 557 persons employed by the dippers, in all 3,131 persons, working an average time of 241.6 days each, received *per capita* for skilled and unskilled labor, $431.06, or an average of $1.79 per day.

* From the Secretary's monthly reports.

Seventeen of Pennsylvania's tin-dipping works were in operation an average of 244 days, in 1895, and employed 557 persons. The aggregate amount of wages paid to these 557 employés was $188,224.32, an average *per capita* of $337.92, or $1.38 for all persons employed. These 17 plants turned out a finished product of 54,873,636 pounds, with value of $2,453,464.68, an average of $89.62 per net ton. In round numbers, Pennsylvania has one-third of the black-plate (tin-plate) manufactories in the country, and over 50 per cent. of their entire capacity. The Pennsylvania works undoubtedly represent some of the largest, best equipped and most successfully operated tin-plate plants of any country.

ELECTROLYSIS OF CHLORIDES.

The *Electrical World* summarizes the conclusions of Andreoli on the relative value of the several commercial processes for the electrolysis of common salt, in these terms. He considers the Castner process far superior to that of Richardson and of Holland. Mercury is used, not as a cathode, as is generally believed, but as a diaphragm; stress is laid on the absence of hypochlorite, which is a serious drawback in the other process; his anodes are made of retort carbon submitted to a very high temperature in contact with different substances. The method of Hargreaves, based on the use of porous partitions on each side of the positive compartment, and of the two dry negative compartments, is said to give a yield of 92 per cent. The results obtained with the Le Sueur process, it is claimed, do not bear comparison with the others. According to Hargreaves, it is better from a commercial point of view to make carbonate of soda than caustic soda. Each of the three processes are absolutely different from the other, and Andreoli considers it an accomplished fact that they have solved the problem commercially. Electrolysis can compete with the chemical methods as far as purity and cheapness are concerned, and the electrical method is far superior as regards simplicity of installation, besides being more sanitary. The Hargreaves process, in the author's judgment, promises to be the cheapest.

PIG IRON PRODUCTION IN THE FIRST HALF OF 1896.

Mr. Swank publishes, in a recent issue of the Bulletin of the American Iron and Steel Association, the following statistics of the production of all kinds of pig iron in the United States in the first half of 1896, viz.:

The total production of pig iron in the United States in the first half of 1896 was 4,976,236 gross tons, against 4,087,558 tons in the first half of 1895, and 5,358,750 tons in the second half of 1895. As compared with the first half of 1895, there was an increase in the first half of 1896 of 888,678 tons, and as compared with the second half of 1895, there was a decrease of 382,514 tons.

The production of pig iron of Bessemer quality in the first half of 1896 was 2,793,672 gross tons, against 2,402,023 tons in the first half of 1895, and 3,221,672 tons in the second half.

RAILROAD BUILDING IN 1896.

The records of the new railroad building in the United States in 1896, which have been gathered by the *Railroad Gazette*, show that 717 miles of road have been built in the first half of the year. The total is not very different from the amount of new railroad which has been constructed in the first half of any year, since the conditions in 1893 called a sharp halt in railroad building. Last year 622 miles of new road were built up to July 1st, and the record in 1894, only 495 miles between January 1st and July 1st, showed how decisively extension work had been stopped. Figures as to the new track built in the first half of the year for seven years past make some interesting comparisons:

1896.	1895.	1894.	1893.	1892.	1891.	1890.
717	620	495	1,025	1,284	1,704	2,055

It will be seen how greatly railroad extension has been checked by the conditions of the past few years, and there are no substantial signs to encourage the belief that any large relative increase is to be expected in the near future.

TECHNICAL NOTES.

Tin Scrap.—The *Engineering and Mining Journal* quotes the statement of Mr. Swinburne, of London, in a recent lecture, that it was easy enough to recover tin from scrap electrolytically in a solution of hot caustic, but the difficulty was to find the scrap from which to skin the tin, as no one seemed to have any for sale. We may note that a considerable quantity of tin scrap is shipped from this country to Europe, chiefly from Baltimore. It is gathered up from the factories which supply the extensive canning establishments of Baltimore and the Eastern Shore.

A Magnesium Light for photographic purposes is described in the *British Journal of Photography*, as a safe and efficient substitute for magnesium wire or ribbon, which is known to be more or less unreliable.

The new method of burning the metal is said to offer a perfectly satisfactory "actinic combustion." The method of preparing the medium is described as follows:

It consists in the "sandwiching" of magnesium powder between sheets of paper impregnated with potassium chlorate. Magnesium powder is placed between two sheets of paper, which have been pasted over with starch. The whole, when dry, forms one single sheet. Next, each side is covered with a piece of paper impregnated with potassium chlorate, and the whole covered with a further sheet of paper pasted on each side, a thick sheet, almost like card-board, being thus produced. It may then, when perfectly dry, be cut into lengths and ignited as required. According to the *Journal of Chemical Industry*, the combination is quite safe and keeps well.

BOOK NOTICES.

Chemical Experiments, General and Analytical, for use with any text-book of chemistry, or without a text-book. By R. P. Williams, Instructor in Chemistry in the English High School, Boston, etc. Boston: Ginn & Co. 1895. Price, 60 cents.

The author gives in this work a series of illustrated practical lessons in chemical manipulations and in analytical work, arranged in a rational order to meet the requirements of the chemical student. The book should prove of value in supplementing the analytical guides employed in the laboratory, and instructors in chemistry will doubtless be quick to apprehend its utility.

W.

A Prime of the History of Mathematics. By W. W. Rouse Ball, Fellow and Tutor of Trinity College, Cambridge. London and New York: Macmillan & Co. 1895. Price, 65 cents.

The author's purpose in this primer is to give a popular account of the history of mathematics, with some notice of the lives and environment of those to whom its development is due; and it is intended chiefly for the use of teachers and learners, to whom the larger works on the subject are not accessible, or who may not have the time to read them. The sketch will be found both interesting and useful to those engaged in the study of this branch of science.

W.

The Chicago Main Drainage Channel. A description of the machinery used and methods of work adopted in excavating the 28-mile drainage canal from Chicago to Lockport, Ill. By Charles Shattuck Hill, C.E., associate editor *Engineering News*, etc. With 100 illustrations and an index. New York: Engineering News Publishing Company, 1896. Price, $6.50.

The engineering fraternity at home and abroad will, doubtless, prove duly appreciative of the opportunity afforded by this publication of obtaining in collected form the valuable series of articles on the great drainage canal of Chicago, which appeared in *Engineering News* during the past year.

The author very justly refers to this undertaking, now rapidly approaching completion, as one of the greatest works of constructive engineering in the world—a statement that will doubtless be received with surprise by many who have given the subject only incidental attention.

The present book contains an historical sketch of the causes which originated the enterprise, and describes in elaborate detail and with a profusion of illustration its engineering features and the methods and machinery employed in its excavation. It will be found especially valuable for reference, from the incorporation therein of full tables giving the cost of every portion of the work.

It is interesting to note the fact that this excavation was of a very variable nature, on which account, and because of the policy pursued of letting out

the work in short sections to many individual contractors, the progress of the work served the useful purpose of developing a great variety of methods of doing the work, thus affording the professional observer an excellent opportunity of comparing the results and forming an intelligent judgment of the comparative efficiency of many different machines. This element is rendered more valuable from the fact that many of the methods and devices developed were extremely novel.

The author has made numerous additions to the articles as they originally appeared in *Engineering News*, and has revised the data to date of publication. W.

The Mineral Industry: its Statistics, Technology and Trade. United States and other countries. 1895. Edited by Richard P. Rothwell, Editor of the *Engineering and Mining Journal*, ex-president American Institute of Mining Engineers, etc. Vol. IV. New York: The Scientific Publishing Company. 1896. Price, $5.

The annual volume of "The Mineral Industry," edited by Mr. R. P. Rothwell, the editor of the *Engineering and Mining Journal*, fortunately for all interested in the progress of mineral and metallurgical industries, appears to have become an established institution.

There is no publication, so far as we know, that compares with it in the extent and completeness of its statistical data, and in the variety of subjects embraced therein in the form of special contributions.

The present volume constitutes the fourth of the series which we have had the pleasure of reviewing, and, like the others, contains a vast amount of valuable material, well classified and arranged for reference.

The editor has been as fortunate as in the earlier volumes, in securing the services of many eminent specialists, in the preparation of special chapters, and the volume before us will add substantially to the value of the series, which has become an indispensable work of reference. W.

Matte Smelting: its principles and later developments, with an account of the pyritic processes. By Herbert Lang, mining engineer and metallurgist. New York: The Scientific Publishing Company, 1896. Cloth, price, $2.

Mr. Lang's contribution to the subject of matte smelting will be appreciated by metallurgists as an intelligent effort by a competent expert to give an independent systematic treatment of this generic class of processes. Heretofore, they have been discussed in connection with copper smelting, silver smelting, etc. Mr. Lang's treatment affords a better and more scientific view of the method.

The various methods, such as the reverberatory, pyritic and German systems, are treated in detail.

The series of tables given at the close of the volume embraces a great amount of valuable information respecting ores treated, fluxes and fuels, products obtained, results of assays and other important data.

The work is an original and valuable contribution to the technology of this important class of metallurgical methods. W.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, September 16, 1896.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 16, 1896.

JOS. M. WILSON, President, in the chair.

Present, 105 members and visitors.

Additions to membership since last report, 6.

Mr. S. Albert Reed, of New York, by invitation, presented a communication, giving a *résumé* of the plan and scope of the important experimental work now being carried on by "The Committee on Fire-proofing Tests." This committee is appointed by the Architectural League of New York, the Tariff Association of New York and the American Society of Mechanical Engineers, to investigate and test methods of fire-proofing structural metal in buildings and to obtain data for standard specifications.

The speaker illustrated his subject with the aid of a series of lantern slides, showing the furnace and other apparatus used in making the tests, and the appearance of the specimens (steel and cast-iron columns of standard sections and actual size employed in buildings) before and after being subjected to the action of fire, and of fire and water, while being maintained under a uniform load (82 tons). The communication evoked considerable discussion, at the close of which the speaker received a vote of thanks. The paper of Mr. Reed will appear in the *Journal.*

Mr. C. J. Reed, of Philadelphia, exhibited in operation the so-called carbon battery, devised by Dr. Jacques, of Boston, Mass., and gave a critical discussion of the principle of its action. Mr. Reed's experiments appeared to demonstrate, beyond reasonable doubt, that the cause of the development of energy in this apparatus is thermal, and not, as has been claimed, electrolytic.

The speaker also exhibited and described what he termed a thermotropic battery, which depended for its action upon certain new and interesting thermo-electric phenomena which he had observed. (Mr. Reed's paper will be published.)

The Secretary exhibited and made some reference to certain specimens of a product called "ductile cast iron," manufactured by the East Chicago Foundry Company, and presented therewith the records of several series o physical tests of the same, which were submitted by the manufacturers in substantiation of the claims made for the product.

The meeting passed a vote of thanks to the members of the Board of Managers and others who had contributed to the expense of repainting, papering and decorating the lecture room, and the meeting was adjourned.

WM. H. WAHL, *Secretary.*

JOURNAL

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OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXLII. NOVEMBER, 1896. No. 5

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, September 16, 1896.

MR. JOS. M. WILSON, President, in the chair.

WORK OF THE COMMITTEE ON FIRE-PROOFING TESTS.

BY S. ALBERT REED, PH.D.

The Term "Fire-Proof."—Fire underwriters use the term fire-proof generically, denoting a class of construction in which no structural member is combustible, with full appreciation of the fact, however, that fire may cause complete wreck without actual combustion of the structure. Some of those practically interested have undertaken to investigate the causes and nature of damage from fire to this class of structure. A co-operative committee of three was formed nearly a year ago, representing officially the principal associations of Fire Insurance Underwriters, the Architectural League and the American Society of Mechanical

Engineers. This committee has done little more, so far, than to construct its plant and to make a beginning of its tests. The results, so far, are, however, for interest and importance, a justification of its expectations.

Growth of Fire-Proof Construction.—With regard to the modern fire-proof building, the situation must be accepted as we find it. It is futile to argue whether or not we should approve of the erection of 25-story steel cages without sustaining walls. Such structures are already thronging our cities and, although we may eventually regulate and restrain many of their eccentricities, we must adapt ourselves to them. Moreover we shall doubtless witness within a generation the transformation of our construction very extensively in this direction.

Only ten years ago there were comparatively few of the fire-proof type in the United States, and these were mainly office buildings or public buildings. In the great Chicago fire there were but three of this type (see *Plate 1*); in the Boston fire none. I do not refer to newspaper reporters' fire-proof buildings, but to fire underwriters' fire-proof buildings. To-day we have over 500 in New York and over 200 now going up. In Chicago there is a large number, and in Philadelphia and Boston and elsewhere the style is rapidly becoming familiar. In England and on the European Continent the type has long been general for mills and factories. In Paris, in 1892, I found no buildings, not even dwellings, being erected other than fire-proof, and fire-proof also with a good protection of structural metal.

Fire Classification of Construction.—Fire underwriters consider three types of buildings:

(1) Ordinary construction.
(2) Slow-burning construction.
(3) Fire-proof construction.

Inasmuch as all three may have brick exterior walls, elevators and stairways in brick enclosures, and no hollow or combustible finish, the distinction does not depend upon those elements, but is found in the floor and column construction.

In the slow-burning type the aim is either, as in the mill

type, by massiveness and avoidance of excessive wood surface, to produce a building which will retain structural integrity even after a quite extensive burning, or as in the protected wooden beam type, the aim is to armor the structural wood against ignition and combustion.

In both of the slow-burning types an essential to the fulfilment of the purpose is that human or mechanical aid shall be competent, if allowed sufficient time, to extinguish the fire. In the fire-proof type, the reliance is on passive brute resistance to survive a fire without structural impairment in spite of a possible complete failure of human aid, which failure may be due to repulse on account of heat, smoke or breakdown, or on account of inaccessibility to the work of fire-apparatus due to great area or great height. The case is similar to that of the fast unarmored cruiser compared with the heavily armored battleship, the one relying for defence upon human activity and courage, and the other upon brute passive resistance to any injury which may be vital, while admitting the probability of very great injury short of vital. For many purposes the second type of construction may be satisfactory or even better than the third, but in a conflagration, as in a pitched naval battle, any type other than the third would be hopelessly outclassed.

Essentials of a Fire-Proof Building.—In modern fire-proof construction, the bold stroke of abolishing the exterior wall as a sustaining member, and relegating it to the function of a screen, was really only a climax of the inevitable, and a frank recognition of the fact that already the sustaining feature was, in large buildings, practically only a formal survival of the organ of an extinct function, like the tail buttons of a man's coat. The old-time warehouse was ordinarily 20 to 25 feet wide, the beams spanned the entire width and were carried by the side walls, while the front and rear walls were not bearing walls. In a modern large building, say 150 x 100 feet, the floors are twelve-thirteenths supported by the columns and one-thirteenth supported by the walls. Furthermore, if the walls are full of windows on all sides, it is merely the piers between the windows which are carriers of weight. In short, a large

building consists, structurally, essentially of its floors and roof and columns; the exterior walls, like the partitions, are screens or fire-stops. Furthermore, when we pass a height of 4 stories, few walls have any stability apart from the guying and bracing effect of the interior.

In a large building of ordinary construction, with brick walls, the term "brick building" is a misnomer. If the building is 6 stories high and 100 x 150 feet, the structural material figures as follows:

	Per Cent.
Brick walls, cubic feet	50
Lumber in floors and columns (about 500,000 lumber feet)	50

In an old-time building, 25 x 60, 4 stories high, the term brick building was more appropriate, as the proportion is:

	Per Cent.
Brick walls	75
Lumber	25

It was, thus, an easy step to abandon the exterior wall as an essential structural member. Therefore, while I would not underestimate the importance of constructing exterior walls so that they shall be efficient screens against external fires, yet it is a fact that, structurally, a modern fire-proof building consists primarily of its steel or iron skeleton and its floor and roof arches.

Duty of a Fire-Proof Building.—Finish or trim is usually more or less of combustible material, and is not expected to survive a fire; but a fire-proof building does not fulfil the duty proper to its type unless, for the fire ordeal which it is likely to be called upon to sustain, its skeleton shall be able to emerge from that ordeal with its structural integrity unimpaired, its floor and roof arches damaged only superficially or locally, if at all, and with its exterior walls, if not perforated by windows, having successfully excluded any external fire.

As regards the contents, if the fire is an external one, and has attacked the fire-proof building on a side full of windows without fire-shutters, we must anticipate a possible total destruction of contents. If the fire is an internal one, we may, provided we have cut off all vertical passages com-

pletely, anticipate a confinement of fire mainly to the floor where the fire has originated. But, in any case, even where fire has extended throughout the building, and all contents, together with finish, trim and mechanical plant and exterior wall ornamentation, are destroyed or wrecked, we must, in our ideal building, demand that it shall emerge from the ordeal unimpaired as to skeleton, and mainly unimpaired as to floor arches.

Relative Importance of Features.—Our investigation then will examine, in order of importance, how fire affects—

(1) The skeleton.

(2) The floor and roof arches.

(3) Walls and partitions regarded as fire-stops.

Fire underwriters will lay the most stress upon the protection of the skeleton, inasmuch as even a local damage may, by throwing the building out of line or plumb, or by dropping out the floor arches, involve the insurer in a total loss, due to the possibility that total demolition may be demanded by building laws, whereas the building may lose a very considerable section of the floor arches without such consequence.

Determination of the Plan of the Tests.—The varieties of fire-proof construction have reference mainly to the various devices for floor arches spanning the space between the steel beams, and such are largely the subject of patent rights. Quite a number of fire and water tests, mainly proprietary, have been made and are being made on floor arches, and those persons interested have already provided quite a fund of data on that subject. But investigation of the protection of the skeleton has not called forth the activity of patentees, and the heavy expense necessary has prevented others interested in ascertaining the facts from going thoroughly into the subject, until we took it up. I will partly except the Hamburg tests, which I will quote later. We determined that our test of the steel skeleton, namely of steel or iron columns, girders and beams, must be made on a full working scale and under the actual conditions, as far as possible, which would obtain in a fire. The only open questions were what fuel to use in generating

heat, at what temperature to work, and what time to require for each ordeal. We decided to use gas for fuel, to work at three typical temperatures, these to represent three typical classes of ordeal that buildings are likely to be called upon to sustain according to their location and occupancy, and to test each case to destruction if possible.

Typical Temperatures.—(1) Say 2,500° F., six hours. A conflagration ordeal for any building, or an occupancy ordeal for a building full of a stock of goods, such as furniture, for example.

(2) Say 1,200° F., one hour. An ordeal for a building subject to possibilities of mild external fire, or to the internal risk of moderate aggregations of combustible material, such as ordinary merchandise.

(3) Say 700° F., one-half hour, representing very mild conditions, such as would occur in an office building or dwelling in an office building or dwelling neighborhood.

It was debated whether the combustion of gas represented actual practical conditions, and whether wood fuel would not more nearly represent those conditions. It was decided to use gas on the following grounds :

(1) The damage to skeleton and floors, which is likely to affect their structural integrity, is almost entirely a matter of temperature, and 1,000° F. of heat is 1,000° F. of heat, no matter from what kind of fuel it is obtained, provided it is applied uniformly.

(2) To undertake the imitation of actual practical conditions would mean to go through the entire list of combustible merchandise—dry-goods, groceries, furniture, clothing, etc.—plainly an absurdity ; whereas, having once recorded our test temperatures accurately, it is open for an independent series of tests to ascertain what temperature and heat units the combustion of any desired kind or quantity of merchandise will develop.

(3) It is so essential that, in successive tests, as nearly as possible uniform conditions should exist, that we must positively have a perfectly controllable source of heat, and gas is eminently such a source. I will add that the advice of Professor Morton, of Stevens Institute, concurred with this decision.

Program to Include Test of Extreme Conditions.—Considering the plan of operation, it is necessary to bear in mind:

(1) That these tests were to be primarily aimed at obtaining data for standard specifications, and, as such, should not be allowed to degenerate into merely patentees' competitions. We decided, therefore, not to finance the undertaking by certificate fees from material men, but entirely by voluntary subscriptions from those interested with the users and not with the producers of fire-proof buildings. From the data we hope to obtain we shall be able to state the requirements for a standard building, for the particular set of conditions, internal and external, which the building is to meet. To be a standard it must contemplate all fire possibilities, even the most remote, pertaining to those conditions. This is not demanded in ordinary construction, but it is in fire-proof construction. It is not intended to advocate a prohibition of fire-proof buildings short of standard, but to establish a standard as a datum level from which allowable variations may be determined. A building which is placed in a conflagration district must, if standard, be prepared for the temperature and the duration of conflagration, and prepared to emerge therefrom structurally unimpaired. Such a survival of a conflagration, even with a damage of 75 per cent. of value, would be a matter of great importance to both owner and underwriter.

Conflagration Conditions.—A conflagration is attended with defeat of efforts at extinguishment, withdrawal of fire department, and abandonment of the field. No building will then survive except such as can offer successful passive resistance to very extreme temperatures sustained over unusual length of time. The surprising phenomena witnessed in large conflagrations, phenomena which are apt to draw out all sorts of fanciful theories to account for them, can all be accounted for if we admit the existence of extraordinary temperatures. Extraordinary temperatures are best obtained for experiment by a judiciously applied blast of air, the air being previously heated to a quite high temperature. Temperatures over 2,500° F. are thus easily obtained. Bunsen obtained a temperature of 3,600° F. with hydrogen and

air, and 5,150° F. with hydrogen and oxygen. In a conflagration the powerful currents of air generated have an opportunity, by passing over highly heated objects, to attain the effect of a genuine hot blast, such as is familiar in metallurgy. Then the effects of heat radiation are exhibited in conflagrations on an entirely unfamiliar scale. Radiation is a much under-estimated factor. It can be easily calculated that a sheet of flame 60 x 60 at 2,500° will heat a point 60 feet away to the point of ignition of wood. It must also be borne in mind that radiation is independent of the direction of the wind. Furthermore, intensely heated air, even without flame, impinging upon combustible objects, may bring them to the point of ignition. It is not so difficult, in consideration of the above facts, to account for the long range at which the effects of a conflagration are propagated. The writer witnessed a practical exhibition of the long range effects of heat radiation at the great fire of April, 1889, at Fifty-ninth Street and Eleventh Avenue, New York, when a large lard refinery burned and the fire spread to an adjoining warehouse, three grain elevators of the N. Y. C. R. R. and two of its covered piers. This is the largest fire that has occurred in New York for many years past. During the height of the fire in the lard refinery, before it had spread beyond, but after the walls had begun to fall, I found the nearest point to watch the fire was 200 feet away, across a vacant lot south, where I could face the blaze only by applying my eye for short periods to the crack of a board fence. (See *Plates 4* and *5*.) The sheet of flame from the fire was at this period at least 150 feet horizontal by 100 feet vertical, and although the wind was blowing away from the fence which shielded me, yet the fence was ignited a short distance away. It is needless to say that the fire department had long since been driven away by the heat and were under shelter.

The temperature of this sheet of flame must have been not far from 5,000° F. to produce such an effect.

We estimated the probable course of our tests as likely to run over several years and to cost fully $10,000. We decided to begin with tests of columns and then proceed to tests of girders and beams, and finally of walls and parti-

tions; and, inasmuch as the main issue we were to settle would be, what kind of protective material or armor around columns, girders and beams should be the standard, the first essential was to ascertain what is the actual nature of the damage caused by fire, or by fire and water conjointly, upon those members without any protection.

Description of Testing Plant.—Our testing plant having been completed late in the spring of this year, we have conducted and completed during the summer the first series of tests, viz.: those on unprotected columns.

The plant consists of a furnace for testing columns and walls and partitions, and a furnace for testing girders, beams and floor arches. A gas-producer, such as is used in iron and steel works, with its attendant boiler, supplies the fuel. There is also a hydraulic pump for applying the working load and a small house for sheltering the pyrometric apparatus.

The column furnace has an arched fire-brick roof, supported independently of the walls, and intended to be permanent. The products of combustion escape through openings between the top of the walls and the arch named. Steel beams under the furnace and one over the top are connected by steel uprights, forming a quadrilateral vertical frame independent of the furnace, and between the upper and lower members of which the column is pinched by a hydraulic ram at the under side. The column passes through the floor and roof of the furnace.

The gas is admitted through iron nozzles in the floor and the jets of flame do not impinge upon the columns. Naphtha is fed into the gas main to intensify the heat.

The beam and floor furnace is completed, except for the superstructure, and will take sections of floor 27 x 12 feet.

Details of Tests.—Test No. 1. Carnegie Steel Zee-bar, 12-inch column. Breaking load, 342 tons; working load, 80 tons; but ram worked poorly, so a load of 48 tons was all that could be obtained. Temperature, 1,200° F. Bent in one hour and twenty-five minutes. Several delays occurred in working the gas.

Test No. 2. Carnegie steel plate and channel column,

12 inches. Breaking load, 303 tons. Tested at working load of 84·8 tons. Bent in twenty-three minutes at a temperature of 1,125° F.

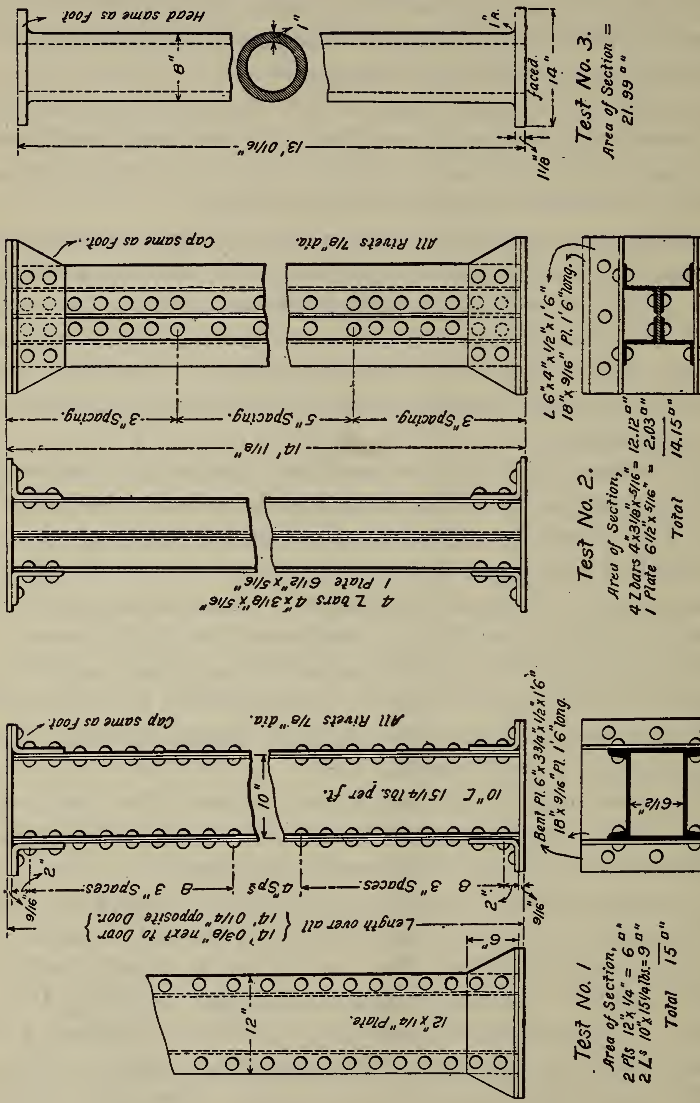


PLATE 9.

Test No. 3. Cast-iron column from Cornell Iron Works. Cylindrical, 8 inches in diameter, 13 feet long; shell, 1 inch

thick. Safe load, 90·2 tons; tested with load of 84·8 tons. Bent at about 1,100° F. in one hour and ten minutes. No water applied. Slow increase of fire.

Test No. 4. Cast-iron column, same as above. Tested with 84·8 tons load. Bent at 1,550° F., in thirty-five minutes. No water applied. Rapid increase of fire. Eight minutes after the column began to bend it broke in the middle.

Test No. 5. Cast-iron column, same as above. Tested under a load of 84·8 tons.

Heated to 525° F. and water thrown on.

Heated again to 775° F. and water thrown on.

Heated again to 1,050° F., showing red heat, and then water thrown on.

Heated again to 1,300° F., showing red heat, and column beginning to bend, water again thrown on.

No fracture of any kind resulted. The temperature was measured by an Uehling & Steinbart pyrometer.

(See *Plates 8*, *9* and *10*.)

The tests will be continued at an early date and will proceed with tests of

Protected columns.

Unprotected columns and beams.

Protected girders and beams.

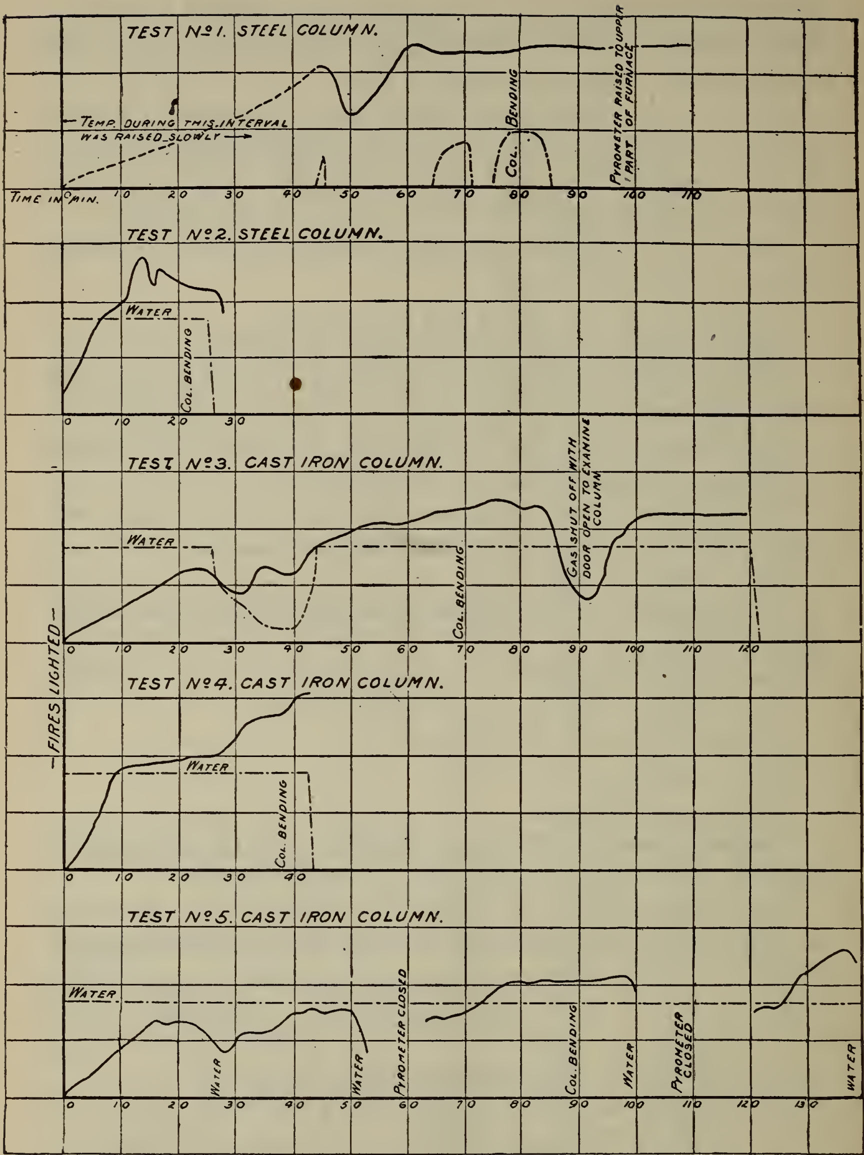
Floor arches.

Walls and partitions.

Probable Nature of Injury to Skeleton.—So far as we may theorize in advance of our tests, I would say that:

Iron or steel must be armored by a sufficient thickness of non-combustible material, of slow heat-conducting quality, and having mechanical properties which are not seriously altered by very high temperature. This armor must be mechanically attached, so that neither heat, falling objects nor fire streams shall seriously impair it.

In order to see more clearly what the task of the fire-proof armor of the steel skeleton of a fire-proof building is to be, we decided in our tests to look first into the effects of fire upon a similar skeleton without such armor. (See *Plates 2* and *3*.) In this matter it is to be noted that the important effects were not those currently reported as



Temperature is indicated by Full Heavy Lines, Vertical Spaces = 500° F.
Hydraulic Pressure by Dash and Dot Lines, Vertical Spaces = 50 tons.

PLATE 10.—Graphical record of tests.

occurring in fires. Thus, expansion appears to be of minor importance as a destructive agent. Personally, I consider that what is commonly reported after fires as warping or twisting is improperly so described. The peculiar twists of the steel beams and girders observed in the wrecks of this class of buildings after fires are due to the shock of the fall, the impact of other objects, and such bending as the member obtains while subjected to stress while red hot. It is a mistaken idea to figure to ourselves steel members warping or twisting as strips of paper will do when hung in front of a flame, a phenomenon due to unequal drying. The effect of fire upon iron can be noted in a common stove. The fire-box must be kept lined with fire-brick, otherwise the shell is damaged. The ash-pit must be kept free from live coals, otherwise the grate bars will become sagged. By thus keeping the lower side of grate-bars below a red heat, the upper side may be at times at a red heat and yet no permanent deformation results. If the whole bar gets red hot it sags from the weight of the coal and does not recover its shape on cooling, but assumes a permanent set and deformation. But, doubtless, with a cool ash-pit the grate-bars, under the influence of the fire over them, curve slightly with the convexity upwards, but upon cooling they recover their normal shape.

Nature of Injury to Cast-Iron Columns.—Due, doubtless, to the heavy expense, no such tests as these have ever before been made on a full working scale. The Hamburg tests of 1894 were made on full-sized columns; but, probably from economy, they applied the heat only to a limited portion of the middle of the column, and, though they brought out important facts, they missed the mark at which we aimed; and, furthermore, missed entirely, by the very fact of local heating, the results which we got with cast-iron columns. While we showed similar though more complete results on riveted steel columns, we also showed for the first time the fire conduct of cast-iron columns in a fire with or without water. It is interesting to quote the prediction made by Mr. John C. Freeman, in a paper read before the Engineering Department of Cornell University

in 1894, as to this point (p. 39). Mr. Freeman asserted that the popular idea that hot cast-iron columns shatter like glass when water strikes them, is erroneous, and our tests fully substantiate this view, although we shall not consider it settled until we have experimented on some of the older styles of very thin steel columns. I have not, however, found any one yet who anticipated the quiet and smooth bending effect of a normal load upon a red-hot cast-iron column, just as a heavy lead pipe might be expected to act if used as a supporting column; nor has our provisional conclusion from these tests been anticipated, namely, that there is no particular choice between unprotected cast-iron and steel columns as to their fire value. Both yield by bending at a red heat about in the same manner, and will eventually double up. But the cast-iron column appears, from tests (3), (4) and (5), to have continued to resist; that is, to have retained some sustaining power throughout the period of bending, whereas the steel column ceased almost entirely to resist; that is, lost practically all of its sustaining power as soon as the buckling began. On the other hand, the cast-iron column broke in two after bending a little way, whereas the steel column did not break, and probably would not have broken, even if the bending had been carried completely through. This feature may possibly be noted as a fact in favor of the steel column. It is interesting to note that, when we arrive at the bending heat, it is probable that many fine distinctions are obliterated; that is to say, that it makes little difference whether the columns are accurately bedded, or trued, or plumbed, or whether the quality of the steel or iron is better or worse. While cold, these points are of extreme importance, but at the bending heat their importance disappears. We can understand this by again resorting to the analogy of the lead pipe. If you make a table with three legs—two of wood and the third of lead pipe—and load the table until the lead leg bends, I think you will find that fine distinctions as to the quality of the lead, or the accuracy of the bearing ends of the leg, or the eccentricity of its load, will be largely neglectible unless the leg is very short and thick. Not that

any lack of care was or will be shown in the adjusting of columns for test; on the contrary, the greatest care was shown in these particulars.

I append, in conclusion, the following list of some typical temperatures (Le Chatelier, *Comptes Rendus*, 1892).

	Degrees F.
Bessemer steel converter	2,994
Siemens Martin open-hearth furnace	2,876
Regenerative furnace, crucible steel	2,912
Blast furnace—gray pig	3,506
Siemens glass furnace	2,390
Siemens porcelain furnace	2,498
Incandescent electric lamp	3,272–3,812

An approximate formula for computing the distance at which a sheet of flame will ignite wood by simple radiation, knowing the approximate radiating area of the flame, is as follows:

$$D = \sqrt{\frac{A\ T}{6000}}$$

in which

D = distance between the flame and the wood to be ignited.
A = radiating area of the flame in a vertical plane.
T = temperature of the flame in degrees Fahrenheit.

The speaker illustrated his subject liberally by the use of lantern slides.

[At the close of the discussion which followed the reading of the paper, the meeting passed a vote of thanks to the speaker for his interesting and valuable communication.]

MODERN THEORIES OF FERMENTATION, WITH NOTES ON THE MORPHOLOGY AND CULTURE OF YEASTS.*

BY DR. FRANCIS WYATT.

[*Concluded from p. 286.*]

I must not allow myself to wander too far into this fascinating field of bygone controversies, but I must dwell upon one point in Pasteur's work, which had a most important bearing on the fermentation industries. He had observed, in some of his determinations, that when yeast and a saccharine solution were kept in an air-free flask, the proportion of yeast produced to sugar consumed was much smaller than it was when a similar solution was kept in a shallow vessel and freely exposed to the atmosphere.

He found that when yeast cells are very young and very vigorous they are able to promote fermentation in a suitable medium out of all contact with air. He also found that mature yeast induces fermentation very slowly under similar conditions, and that the resulting cells are invariably of abnormal shape. Finally, he observed that if really old yeast is employed in air-free media, no cell reproduction at all takes place. The yeast does not die, but it remains dormant, as may be shown by the fact that if the liquid be ærated after some time, either with atmospheric air or oxygen, fermentation and reproduction at once go on.

From all these circumstances, as he saw and understood them, Pasteur gathered that, given a suitable quantity of air, yeast can live by direct absorption of oxygen and can produce carbon dioxide gas without requiring sugar. Directly the air is taken away on the other hand, sugar becomes essential *as a source of oxygen*. To put it more plainly, yeast in the presence of air is a fungus or a mould, whereas, in the absence of air, it is a ferment. If yeast can perform its vital functions more readily when it obtains its oxygen in the free state than when it has for that purpose

* A lecture delivered before the Franklin Institute, January 10, 1896.

PLATE I.—Building N. E. corner Monroe and LaSalle Streets, Chicago. View taken immediately after the great Chicago fire. The building was structurally unimpaired.

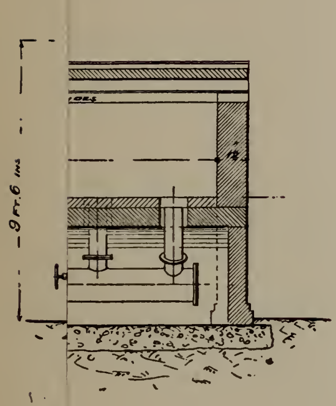
PLATE 2.—Effect of heat from a fire across the street acting through the windows upon a building with unprotected steel girders, Bleecker Street and Broadway, New York.

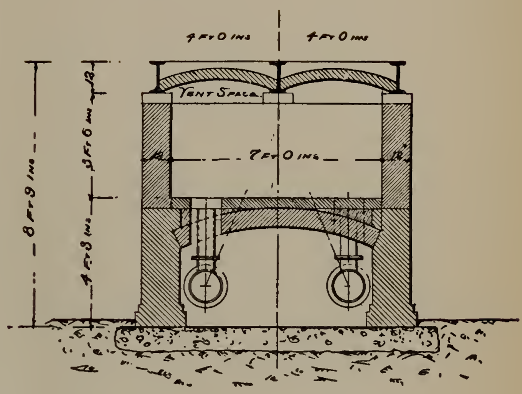
PLATE 3.—Effect of heat from a fire across the street acting through the windows upon a building with unprotected steel girders, Bleecker Street and Broadway, New York.

PLATE 4.—Looking North from Fifty-eighth Street.

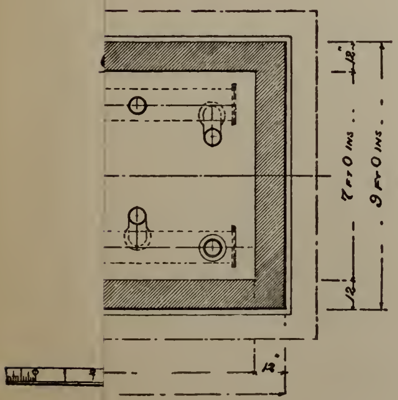
PLATE 5.—The same, from another point of view.

Great fire of April, 1889, at Fifty-ninth Street and Eleventh Avenue, New York.





TRANSVERSE SECTION.



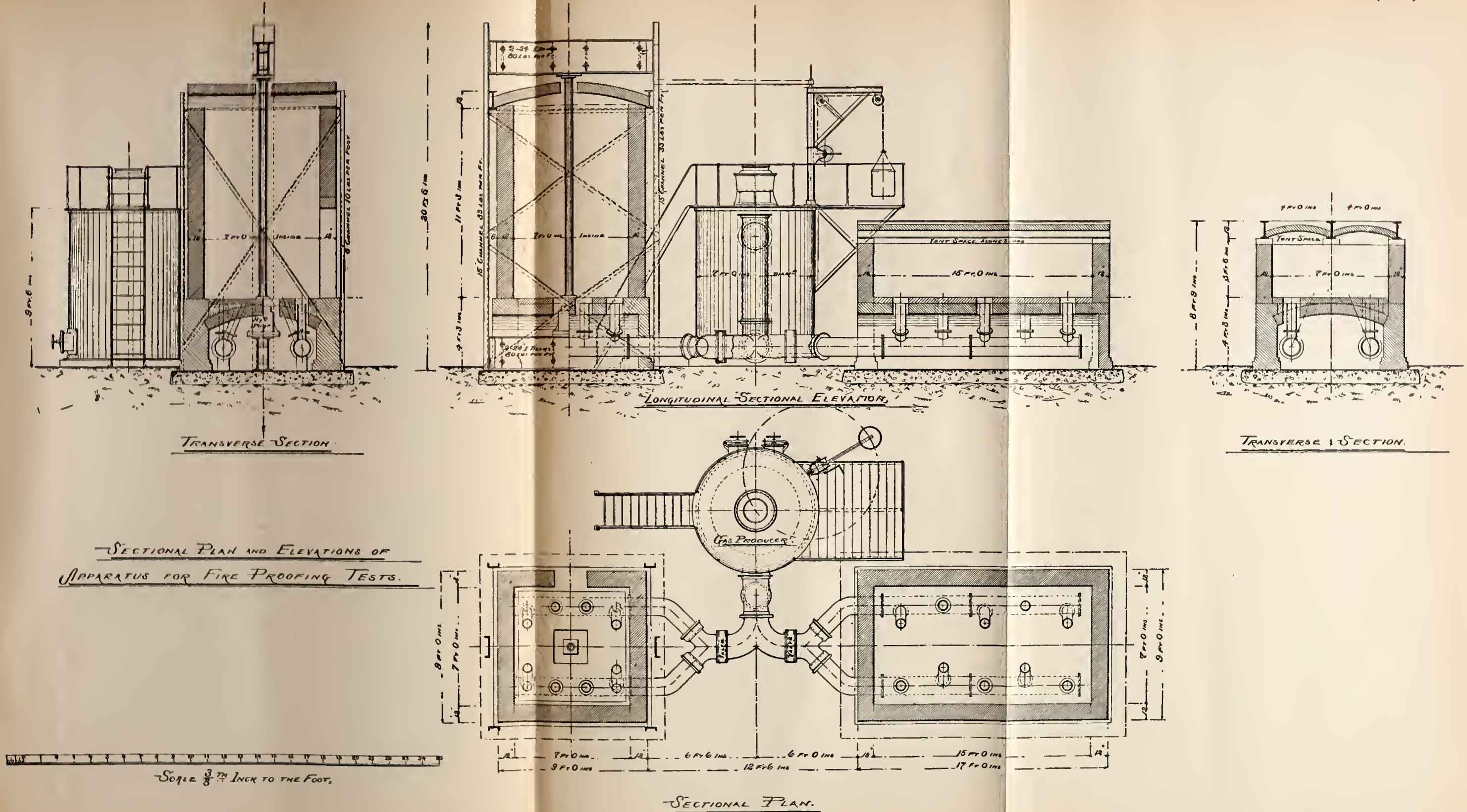


PLATE 7.—Diagram of testing plant.

PLATE 6.—Plant erected to test fire-proofing structural metal in buildings.

PLATE 8.—Views of the columns after the tests.

to effect the decomposition of large quantities of sugar, its life as a fungus is, of course, the easiest. I have noticed, in my own practice, that if yeast be grown continuously in saccharine solutions under conditions which result in the rigid exclusion of air, fermentation becomes more and more sluggish, and I conclude that, the conditions of life being more severe, the struggle for existence is so acute that vitality eventually succumbs. I have recently had special facilities for conducting fermentations on the large scale in one of our largest breweries, in closed vessels, under what is now known to brewers as the "vacuum process," and I have invariably found that when air is excluded there is a certain stage at which yeast reproduction becomes sluggish. By introducing into the liquid at this stage a regulated supply of pure air, so as to thoroughly ærate it by bringing it into full contact with oxygen, I have found that it undergoes a remarkable change, and that the growth of yeast then increases with great rapidity.

If I accept the theory of Pasteur in this connection, I must conclude that by introducing air I cause the yeast to flourish as a fungus on the dissolved free oxygen. I should also have to admit that the yeast ceases its action as a ferment while the oxygen is present, and simply grows and accumulates vital energy. I cannot, in the light of my practical experience and of general recent progress, however, accept these conclusions in their entirety, and I will endeavor to explain briefly the reason why.

In all his experiments in this direction Pasteur *weighed* his yeast, and I think this was in a great measure a mistake. If he had *counted* the cells he would have been able to refer his results to the amount of effect being produced in any liquid by the action of an unit cell. One of our foremost modern investigators is Adrian J. Brown, and he has concluded in this relation that, when any fermentable nutritive solution, such as malt wort, or a solution of dextrose in yeast water, is inoculated with yeast, and kept at a temperature favorable to its growth, the cells reproduce themselves rapidly for a time. When they cease to multiply, the fermentation of the solution does not stop, but is carried

on by the continued life of the cells already formed. No matter what number of cells may be introduced to start the fermentation, the same maximum crop will be obtained, providing the liquid be the same, and all other conditions equal. These are really most important conclusions, and they are supported by Brown, by a reference to the following experiment: Two flasks were taken, marked A and B, 150 cubic centimeters of the same malt wort were placed in each, and then they were treated with a different amount of the same yeast. The contents of the flasks were thoroughly agitated, and the cells were counted by the hæmatimeter. (The standard volume of the instrument employed was $\frac{1}{4000}$ of a cubic millimeter.) The flask A contained 0·93, and the flask B contained 7·44 cells per standard volume. The flasks were kept at 77° F. until fermentation had completely ceased, when the cells were again counted. In flask A the number of cells per standard volume had increased from 0·93 to 25·24; whereas, in flask B the increase was from 7·44 to 27·08. The rate of increase differs widely, but you will notice that the ultimate number of cells produced was approximately the same.

In another experiment more cells were added to the solutions than the maximum number, two similar flasks of malt wort being seeded respectively with 6·0 and 70·8 cells of yeast per standard volume. Fermentation was allowed to proceed, and, at its close, in No. 1 flask the cells had increased from 6·0 to 24·9, while in No. 2 they had decreased from 70·8 to 68·2. In this experiment 24·9 cells may be regarded as the maximum number that the wort used would grow, and, consequently, with No. 2 flask there is no increase, but an actual diminution, which is probably accounted for by the death and disintegration of some of the cells. It was noted in this and many similar experiments that in the second flask, as well as the first, fermentation proceeded with great rapidity, and as this seems to afford us a method of studying fermentation without multiplication of cells, Brown conceived the idea of applying it to the investigation of the action of oxygen on yeast.

He made a malt wort of 1·065 specific gravity and added

yeast to it in the proportion of 85 cells per standard volume; 120 cubic centimeters of this solution were poured into flask A so as to nearly fill it; its mouth was then stopped in such a manner as to prevent the access of air, but not to impede the escape of carbon dioxide gas; 120 cubic centimeters of the same wort were next placed in a large flask B, of about 1,500 cubic centimeters capacity, so as to simply form a thin layer of liquid on the bottom, through which a current of air could be readily drawn. Both flasks thus had exactly similar contents, but the one was small and was kept free from the air, while the other was large and its contents were subjected to abundant æration. The fermentation was conducted at 67° F., and after the end of three hours was arrested by the addition of salicylic acid. The liquids were distilled and the amount of alcohol produced estimated from the specific gravity of the distillate. In the A flask without æration, 3·35 grams of alcohol had been formed, while in the B flask, through which a continuous current of air had been drawn, the alcohol amounted to 3·56 grams. The number of yeast cells had not increased at the close of the experiment, but slight attempts at abortive budding were observable, particularly in the flask B.

In another duplicate experiment which was made, the fermentable medium was a solution of dextrose in yeast water, seeded with 90 cells of yeast per standard volume. At the end of three hours fermentation was stopped, and the residual sugar in the solution in each flask determined polarimetrically. In A (unærated), 1·96 grams of dextrose had been fermented, while in B (ærated), the quantity of fermented dextrose was 2·32 grams. There was no sign in either of the flasks of any budding or enlargement of the cells.

In a discussion of these results, it was objected that the *mechanical* effect of æration might stimulate the action of the cells in the B flasks, and to meet this objection the following pairs of experiments were made, in which the A flasks were subjected to the action of currents of carbon dioxide and hydrogen respectively, and at about the same rates as the air was passed through the B flasks. The

results were as follows, and the interest attaching to them lies principally in the fact that they show that in every case the most work is done in the presence of oxygen :

"A" flask, with passage of carbon dioxide, 3·99 grams of dextrose fermented.

Companion "B" flask, with passage of air, 4·28 grams of dextrose fermented.

"A" flask, with passage of hydrogen, 2·26 grams of dextrose fermented.

"B" flask, with passage of air, 2·45 grams of dextrose fermented.

You will observe that in these experiments the fermentation proceeded very rapidly, and will understand that it did so because Brown employed such large quantities of yeast. In order to watch the result under slower conditions, he made experiments with fermentation at 44° F. continued for twenty-four hours. Through A flask hydrogen had been passed, and 4·882 grams of dextrose had been fermented; in B flask, through which 190 liters of air had been passed in twenty-four hours, the quantity was 5·289 grams. The fact that there was no multiplication of yeast whatever in any of these experiments affords a striking contradiction to Pasteur's great theory, to which I alluded just now, since it proves that *in the presence of oxygen actual fermentation is more vigorous than in its absence.*

In order to dispel any suspicion of difference in results because of difference in methods of estimation, I may mention that Brown made one important experiment in which he weighed as well as counted his yeast. In this case the two flasks A and B were again employed, and, at the commencement, there were in each flask 87·6 cells per standard volume, and 1·903 grams of filtered, washed and dried yeast per 100 cubic centimeters of the liquid to be fermented. Fermentation resulted in the destruction of 6·20 grams of dextrose in the hydrogen flask, and 7·38 grams in the air flask. No increase took place in the number of cells, but the weight of the yeast, after being filtered, washed and dried, did increase very slightly in each case, that from the hydrogen flask being 2·030 grams, and that from the air flask 2·060

grams. The increase is, however, so small as to be practically negligible; and as it is probably due to assimilation, I think it is quite fair to say that in both cases we wind up with almost the *same weight of yeast*, as well as the same number of cells, and hence that equal amounts of yeast, whether determined by weighing or by counting, ferment more sugar when supplied with air than when deprived of it.

As I have been working on almost the same lines with Brown, I have duplicated many of his results with insignificant variations in my own laboratory during my students' experimental course. It was Pasteur's belief that the weight of the yeast formed during fermentation under varying degrees of aëration, and in proportion to the weight of sugar fermented, was an expression of fermentative power, and he argued that the ratio of yeast to sugar must always remain constant, however much or little sugar is available. As the result of what I have just told you, however, you will see that there is absolutely no direct proportion between weight of yeast formed and sugar fermented, and it is not too much to say that the total fermentative power of yeast was never accurately measured in Pasteur's experiments. For various purposes connected with my professional work, I have carried out numerous fermentations under ærobic conditions, in such a manner as to decompose practically all the sugar originally present in the wort. When I have prevented reproduction by seeding with large excess of yeast, and have added sugar to the fermenting wort repeatedly at intervals, until several times the quantity originally present has been decomposed, I have always found that the weight of the yeast has undergone no increase at the end of the operation. Where are we to look for Pasteur's mistake? I cannot enter into a lengthy dissertation, but I will say briefly that in my own opinion it is entirely attributable to the conditions under which he was working. He used too limited an amount of sugar, and carried on his ærobic fermentations in shallow dishes for altogether too limited a time. He also used cane sugar as the fermentable material, and this is an important argument against him. He did not so fully realize, as we do now, that before yeast can ferment cane sugar, it must first

exercise its hydrolytic functions and invert the sugar, and he consequently made no allowance for the time taken up by this preliminary function. Broadly condensing all these facts, I think that, without intending to cast the slightest reflection on the work of the great master, I have shown good reasons for disputing his "life without air" theory, and for substituting for it, as the basis of our modern theory of fermentation, "that oxygen can be used by yeast cells just as it is used by the ordinary ærobic fungi, and that it is probably essential to their proper and continuous reproduction. They can, however, for a time exhibit their full fermentative functions in a propitious medium, independently of free oxygen."

Turning now from the purely theoretical to the more practical phases of fermentation, as we employ and understand that term in the arts, and more especially in that of brewing, there only remains to me sufficient time to draw your attention to the most salient points connected with the cultivation and examination of beer yeasts, as carried on by the modern brewer.

When a minute quantity of yeast is added to some malt-wort, which has previously been filtered bright, and is then kept in a glass flask at a temperature of about 70° F., it will be noticed after a few hours that bubbles of gas will rise to the surface of the liquid. Gradually the liquid will become more and more turbid, and, later on, in accordance with the variety of yeast used, either a sediment will be observed at the bottom of the flask or a scum will collect at the surface, carbonic acid gas being in the meantime copiously evolved. If the yeast cells be carefully examined under the microscope from time to time while this is going on, it will be noticed that at first the vacuoles which were present in every cell gradually disappear, each cell becoming full and rounded in appearance, owing to the absorption through its cell wall of certain nourishing substances from the wort. Some minute buds will be seen jutting out from the sides of the cells; these buds rapidly grow and soon assume the size of the parent cell, from which they finally become detached, but not before they in their turn have developed

other buds, and these yet others, thus giving rise to little groups or strings of cells. This cell reproduction and growth is due to the nourishment which the yeast derives from the wort; but, as I have already explained, for some time after the yeast cell continues to produce buds, and even after the rupture takes place between the parent cell and the resulting daughter cell, the former will continue to absorb various substances from the liquid.

The actual process of alcoholic fermentation cannot be stated with accuracy, but it probably consists in an absorption of carbohydrate substance by the yeast cell, and the splitting up or transformation of this substance into alcohol and carbonic acid gas, the presence of free oxygen being desirable in order that the cell may continue to properly thrive and grow and put forth buds. During the period of growth a fattening of the cells takes place at the expense of certain assimilable or digestible nitrogenous compounds present in the wort, which may be either salts of ammonia, peptones or amides. If neither of these, but only insoluble albumens be present, no fattening takes place, and the yeast becomes starved, as it were, and perishes. On the other hand, it has been my experience that, if there be present a large excess of these nitrogenous matters, the yeast cells become overfed, and their capacity for reproduction becomes thereby considerably diminished.

There are a large number of species or races of yeasts, and they are all characterized by some special action on the different varieties of sugars, and by some special products as the result of that action. Some species, for example, readily ferment dextrose and lævulose, but exert no direct action on cane sugar. Other species secrete a substance known as invertase, which has the power of splitting cane sugar into dextrose and lævulose, and when they have exercised this preliminary inverting function they next proceed to exercise their fermentative powers on the inverted products. Yet other species contain an enzyme known as glycase, which splits up maltose and malto-dextrines into dextrose, and you will thus perceive that in the ordinary yeasts, as we find them in the fermentation industries, we are called

upon to deal with a mixture of races all endowed with different faculties, some of which may be very valuable, others highly objectionable, and some of which may take place within and others without the cell wall of the organism. There can be no doubt that Pasteur was entirely correct when he stated that every form of deterioration in beer or in wine is associated with some particular organisms belonging to a class of disease ferments. Some forms of this class may be readily distinguished from the true *Saccharomyces cerevisiæ* by means of the microscope, but there are others which are not so distinguished because they have all the outward characteristics of pure yeast. Incalculable numbers of these false ferments are always present in the atmosphere, as well as on the surface of all fruits, so that if sweet, unboiled brewers' or distillers' wort be freely exposed to the air, it will, in the course of a few hours, without the addition of yeast, manifest all the outward signs of fermentation. This fermentation will be mainly carried on by wild yeasts and spores of bacteriæ and moulds, and after a few days, if left to itself, the wort becomes quite turbid, is covered with a thin film, emits a disagreeable smell, and rapidly putrefies. If, however, the sweet wort is boiled with hops before exposure to contamination, all the spores which may have been derived from the outside air are killed by the heat, and the wort, being thus sterilized or rendered free from all foreign germs, is more likely, when mixed with pure yeast, to undergo a true alcoholic fermentation.

I have said that our commercial yeasts are a mixture of races, but at the present time it is an easy matter to procure a pure ferment of any desired single special race or character. This stage of our progress we owe to Dr. Hansen, to whom I have already referred, and whose work on the cultivation of absolutely pure yeast of one particular race and of ascertained quality has been brought to a most successful issue. When Pasteur had established his theories as to the cause of disease in beer, Hansen conceived the idea of cultivating pure yeast from a single selected yeast cell, as opposed to Pasteur's suggested plan of purifying yeasts by the addition of certain antiseptics, which were supposed to

have a selective action, and to work upon the bacteriæ and leave the yeasts unharmed. Since Hansen made his first practical demonstrations in the brewery in 1883, carefully selected types of yeast, from pure cultures made by his method, have been introduced into many of the leading breweries of the world with the most marked success. The great advantage offered by Hansen's discovery is due to the fact that the several varieties of each species of ferment can be separated, and that, while they cannot microscopically be distinguished from each other, they are all found, when so separated and used on a practical scale, to give entirely different fermentation products, both as to flavor, brilliancy, attenuation and clarification.

If the microscope does not enable us in some instances to differentiate one form of yeast from another, it has yet enabled us to discover that under certain conditions the yeast cell, instead of throwing out a bud, multiplies itself in another way, its protoplasm dividing itself into four masses, termed acrospores. Each of these acrospores surrounds itself with a cell wall, and the whole of them are finally set free by the dissolution of the cell wall of the parent. Now, Hansen observed that pure and normal bottom fermentation yeast forms spores at 77° F. only after some days, whereas nearly all the wild species which communicate objectionable qualities to beers are capable of forming acrospores at this temperature in a few hours. You will see, without difficulty, that this is a most interesting and important fact, and will understand that it may be used as the base of a method for the practical analysis of brewers' yeast, which I will briefly describe.

We will suppose that we are called on to examine a sample of suspected brewery yeast. A small quantity is spread on a sterilized block of plaster of paris, and this block is placed in a flat, covered glass dish containing water to keep it moist. The dish is placed in a thermostat or forcing chamber, and kept at a temperature of 77° F. for forty hours. At the end of that time it is carefully examined under the microscope, and if any wild yeast be present, the spores will be seen as round bodies within the cell wall.

According to Hansen's carefully worked out experiments, the principal species of budding fungi with which the true *Saccharomyces cereviciæ* is most commonly associated or contaminated are:

Saccharomyces pastorianus No. 1, which imparts to beer a disagreeable bitter taste and very unpleasant odor, together with a turbidity most persistent in its character.

Saccharomyces pastorianus No. 2, a very feeble yeast, which does not appear to impart any disagreeable odor or flavor, but which prevents clarification.

Saccharomyces pastorianus No. 3, a yeast of very similar character to the No. 2, but productive of more turbidity.

Saccharomyces ellipsoideus and *Saccharomyces exiguus*, which occur on the skins of ripe grapes, and give to beer a very persistent turbidity and a disagreeable, bitter and astringent after-taste.

Saccharomyces mycoderma cereviciæ, a yeast which forms a film on the surface of beer and reproduces itself by budding or by spores, which has a very limited fermentative action and does not directly cause acidity, but which is a powerful oxidizing agent and causes alcohol to be transformed into carbonic acid gas and water.

The species of bacteriæ which may occur in beer are too numerous to mention, but those best known to us arise from yeast contamination or atmospheric infection, and are the *Bacillus amylobacter*, *Bacterium termo*, *Bacterium aceti*, *Bacterium lactis*, *Sarcina* and *Micrococci*. Of the species most frequently met with in old beer, the principal are the ropy ferment, the color bacterium, and certain forms of vibrio, spirillum, etc. The whole of these disease organisms constitute an army which constantly worries and harasses the brewer and keeps him ever on the alert, since they generally develop themselves very freely under favorable conditions, more especially in the finished beer after it has been some time in cask or bottle. I will not weary you with a catalogue of the vices of these germs, but will be satisfied to state that *Bacterium aceti* has the power of converting the alcohol of beer into acetic acid; that *Bacterium lactis* attacks the residual saccharine matter and converts it into lactic

acid, and that the latter, being acted on by the *Bacillus amylobacter*, is, in its turn, converted into butyric acid.

The preservation or contamination of brewers' yeasts, or the maintenance of a given ferment in a state of purity and health, depends almost entirely on the nature of the fluids in which it is cultivated.

The foods of yeasts must be capable, by assimilation, of producing heat and of forming tissue, and they must be made up of a judicious mixture of certain carbohydrates, albuminoids and minerals, in suitable proportions, and in a truly soluble and readily assimilable form. The carbohydrates contained in brewers' worts are the sugars and dextrines produced by the transformation of starch under the influence of the enzyme diastase; the albuminoids are the peptones and the amides, or soluble nitrogenous substances of malt; the minerals are phosphates, sulphates and chlorides, either derived from malt naturally or added to the liquid artificially.

Bearing these elementary principles in mind, we cannot fail to institute the well-worn comparison between good and bad brewers' worts and fertile and sterile lands. Let the wort contain the necessary constituents in suitable proportions, and the yeast plant sown in it, under ordinary and proper conditions of cleanliness and care, will be vigorous and healthy; but let there be either a lack or an abnormal excess of either of the essential components, and the true yeast plant will deteriorate with great rapidity. This deterioration or weakening will allow other germs, for which the liquid is a more propitious medium, to usurp the yeast's place and flourish in its stead. This, of course, is in accordance with a perfectly natural and general law, which applies not only to yeast, but equally as well to all other plants and to man and animals.

Of the two kinds of fermentation known to brewers, the top fermentation is carried on at temperatures between 55° F. and 75° F.; the yeast is eventually conveyed to the surface, and the process generally lasts from four to seven days. The bottom fermentation takes place at temperatures between 40° F. and 52° F., the yeast, by reason of its

greater specific gravity and the sluggish nature of the fermentation, ultimately subsiding completely to the bottom of the fermenting vessel, and the process lasting from ten to fifteen days. Ale is produced by the top fermentation, lager beer by the bottom fermentation, and the scientific grounds on which preference is given to the latter are: That at the low temperature used, fewer organisms develop which are detrimental to the qualites of the beer, and that a sounder and better-keeping beer can, in consequence, be produced.

The difference in appearance between top and bottom yeast is slight—so very slight, in fact, that the one can safely be said to be undistinguishable from the other by means of the microscope.

The kind of microscope best adapted for the use of brewers and distillers is one that will give a magnification of from 600 to 1,000 diameters with a clear and well-defined picture. The comparative purity of yeasts can be determined by it only very roughly and approximately, because good and bad yeast types may have identically the same microscopical appearance; but there are certain characteristic forms of wild yeasts and of harmful bacteriæ which can at once be identified, and for which it is imperative to keep constant watch and ward. Two or three samples of yeast should always be taken for microscopical examination from the tubs after the surface has been skimmed off, and a number of fields from each sample should be subjected to rigorous scrutiny. The preparation of the sample is so easy and expeditious that it is an easy matter for the brewer, who takes pride in his fermentations, to perform several investigations each day. A very small portion of the yeast sample is carefully and thoroughly mixed up in any convenient vessel with some pure distilled water. By means of a rod with a rather fine point, a small drop of the mixture is transferred to a glass slide, and evenly and thinly spread out over a small surface, which is then covered with a thin cover-glass. The slide having been placed upon the stage, the objective is brought into position by means of the fine screw, so that, with a bright light, mirrored from a clear sky or from an incandescent lamp, the organisms become plainly visible.

The yeast cells should be uniform in size and shape, full and plump-looking and transparent, and must contain few, if any, vacuoles or granulations. The cell's wall should be thick and free from pittings, and stand out well against the field. There should be no signs of budding, and no dead or shriveled cells should be present. In order to detect the existence of dead cells, a drop of methylene blue solution may be added to the dilute mixture of yeast under examination. This will stain the dead cells instantly, and will leave the living matter entirely unaffected. It is also a good plan to add to the sample to be examined a small portion of caustic soda or potash solution, in order to dissolve any hop resins or albuminoids that might otherwise be taken for bacteriæ.

In general terms it may be stated that a really good seed yeast should contain no bacteriæ of any kind; but I need hardly say that it is extremely rare to find samples, even from our best breweries, which are not more or less contaminated with some form of foreign or wild growths. As a rule, any sample which contains more than twenty of such forms in every ten fields should be rejected, and a sample in which more than two long rods appear in the same number of divisions should invariably be condemned.

As I have already taken up a great deal of time, I can only give you a very brief outline of the process of cultivating pure yeast from a single cell; but I will, nevertheless, endeavor to make it comprehensible. The operation is, of course, commenced in the laboratory. A minute quantity of the yeast is cultivated in small flasks with sterilized wort. As soon as the fermentation has commenced, the newly formed cells are drawn off to another flask, which contains sterilized water, and which is then well shaken so that the yeast cells get equally dispersed. A drop of this liquid is next examined under the microscope, then dropped quickly into another small flask containing sterilized wort gelatine, liquefied at a temperature not exceeding 85° F. After gentle shaking, this liquid is examined under the microscope, and if it does not show more than one or two cells in a field, one drop of it is spread evenly over the inside of

a cover-glass, divided into squares and placed in a "Boetchers" moist chamber. This chamber consists of a glass ring with ground rims; on the one rim is fastened a cover-glass, the other is to be fastened with vaseline to a glass slip, on which is put a drop of water. As soon as the wort-gelatine has stiffened on the cover-glass the ring is placed on the glass slip, and thus isolated. The whole of this operation is done in a box with glass sides and a sliding door, just big enough to make it possible for the experimenter to manipulate in it, these precautions being taken in order to obtain an atmosphere as quiet and as free from dust as possible. Generally, two or three "Boetchers" chambers are made for each experiment, in case an accident should happen to one of them. As soon as the chambers are finished they must be examined under the microscope with a very low power, so that the cells are just discernible, in order to ascertain whether they are placed so that single ones can be selected and separate growths or cultures be developed. The various cells are then examined, and marked with a colored ring on the outside of the cover-glass round each single cell. This being done, the chamber is placed in an incubator, and kept at a constant temperature of about 85° F. If each colony is now examined, it will be seen to be as large as the head of a pin, and each is now introduced singly into small Pasteur flasks containing sterilized wort. If a culture from only one species of yeast is required, four or five flasks will be sufficient; if from more, four or five flasks are required for each kind.

The Pasteur flasks, the "Boetchers" chamber containing the yeast growths, a tweezers and some small pieces of sterilized platinum wire are all kept in the sterilized air-box. The ring being removed from the cover glass, one of the pieces of platinum wire is taken with the tweezers and with it one of the marked yeast groups is picked out. The wire is then dropped into the wort contained in one of the Pasteur flasks, and the latter is closed as rapidly as possible. In the same manner the wort in the other flasks is inoculated with one of the different yeast groups selected. The flasks containing the pure culture are so marked as to show

from which cells they originate, and placed in the thermostat at 85° F. for forty-eight hours. The contents of the flask are then examined, and those of them which show the same characters are mixed and transferred into larger flasks, and in this manner the work is continued in the laboratory until about 9 gallons of fermenting wort are distributed over four large Pasteur flasks made of copper.

The operations in the laboratory having come to an end, the selected yeast is next cultivated in sufficient quantities for practical use in the brewery, by means of an apparatus similar to that used by Hansen-Kuhle. It is constructed on the same general idea as that upon which Pasteur devised his flask, and is so arranged that it can be erected in the fermenting cellar itself. It consists of three parts:

(1) The wort chamber.

(2) The yeast cylinder.

(3) The aërating compartment, consisting of an air pump and air receiver, the latter with filter of cotton-wool attached.

The wort cylinder consists of a drum with a lid, which, for the purpose of cleanliness, can be readily removed. Inside the cylinder is fixed a copper steam coil, by which the wort can be sterilized. By means of a valve the cylinder is connected with the air in the receiver, and the air is passed through the filter near the valve. It is necessary that a constant pressure of sterilized air be present in the cylinder to prevent infection of the wort by the entrance of outside air. The wort cylinder is connected with the fermenting cylinder by a pipe, and is enclosed in a jacket with an intervening space filled with cold water for the purpose of cooling the wort. The fermenting cylinder is constructed nearly in the same manner as the wort cylinder. It has a perfectly air-tight lid, through which passes an agitator with two end blades, the one being provided with an india-rubber scraper, which sweeps the bottom as well as the sides when in motion. From the lid there issues a double bent pipe, which, when its valve is opened, communicates with the interior of the cylinder, its free end standing in a vessel of water to secure a constant over-pressure.

A little below the lid a horizontal pipe is fixed, whereby the interior of the cylinder can be connected with a vertical glass tube, the top of this latter being connected with a filter, and the bottom with another horizontal tube passing through the lower part of the cylinder. On the side of the cylinder provision is made for introducing the yeast through the pipe.

The air is filtered before it enters the pump, and later on it is more perfectly purified through the filters on the cylinders. The receivers must be strong enough to stand a pressure of 80 pounds. After the wort has been sterilized, well aërated, and refrigerated in the wort cylinder, it is introduced into the fermenting cylinder, which has previously been sterilized and supplied with the suitable quantity of pure yeast. The yeast is stirred up now and then while the wort is passing over, and it is necessary in fact to keep the contents of the cylinder in movement until the fermentation has commenced. During the fermentation, a slight current of sterilized air is allowed to pass through the filter into the cylinder to force out the carbonic acid gas, which has been developed during the fermentation. When the fermentation is finished part of the yeast will have accumulated on the surface, and part of it will have fallen to the bottom. Beer is now drawn from it until nothing but foam comes from the faucet, and then sterilized wort is again introduced into the cylinder until the lower mark on the glass tube is reached. The rouser being put in motion the yeast is stirred up, and the whole process is repeated until yeast sufficient for starting a fermentation in about ten barrels of wort has been obtained. The apparatus is kept in continuous work, and it is only necessary that the yeast taken from the cylinder be constantly subjected to microscopical control. Directly the presence of any impurities is observed, the cylinder must be cleaned, sterilized, and a new pure culture introduced.

Although the cultivation of pure yeast has not yet made much progress amongst the practical brewers in this country, it is quite certain that its advantages only require to be fully understood by them in order to make it an indis-

pensable part of their processes. Its adoption will supersede all the present attempts to secure immunity from the troubles that now constantly arise from the uncertain action of false ferments or wild yeasts and bacteriæ, and will ensure the production of brighter, more stable, and better-flavored beers of any desired type by our modern breweries.

I think I have now gone far enough to establish that all the disagreeable qualities of malt beverages are the directly resulting products of ferments foreign to the true yeast, and to demonstrate that such defects may be obviated without difficulty by excluding these foreign forms from the fermentative medium.

I have not pretended to trace in detail the ways in which, owing to various peculiarities, our present methods have diverged from those that preceded them, because to do this would require an amount of learning and a scope of thought to which I cannot possibly pretend. I have endeavored to give you some general perceptions of great discoveries and truths, and I shall be fully satisfied if some of you seek to follow out these truths and prove them by evidence that will satisfy your own minds. You will agree with me that in such a complicated subject the wider any generalization is, the greater will be the chance of apparent exceptions; and when, as in this instance, certain theories cover a vast amount of space, the exceptions may be innumerable, and yet not destroy in any way the fundamental accuracy of the theory itself. If the general proposition is admitted, it necessarily follows that the adoption of the methods devised by science for the correction of errors and the ultimate attainment of perfection are mere matters of time and education. Men will come and men will go, but true science will remain. It has already sustained the shocks of empires and will always outlive the struggles of rival theories and creeds. Of it we may truly say that it is built upon a rock and must stand forever.

NIAGARA ON TAP.*

By T. Commerford Martin.

[*Concluded from p. 302.*]

We have now reached the point at which we can actually see the energy of Niagara converted into electrical current. There is the water flowing steadily into the intake canal from the main Niagara River, gliding by so smoothly and swiftly. There are the gates through which the diverted water flows to the penstocks. There are the turbines at the foot of the penstocks. There is the shaft set in revolution by the headlong fall of water, and there is the dynamo itself, spinning like a big, fat teetotum, and which, in the very act of spinning, changes the mechanical energy or gravitational effect into electro-magnetic energy and thus yields us that which, for want of a better word, we call current. Curiously enough, the energy that we have just caught up from the river outside, we are going to head back again in the very direction that is contrary to the direction of the water's flow—just as though we had taken a wild Indian runner, seized him by the shoulders and swung him around so quickly that he kept on faster than ever back over his own tracks. We want now to deliver this energy on the spot as well as at Buffalo and lots of other places even more than 20 miles away, and we want to prove, on a grand scale, the absurdity of that wise old adage which says that you cannot grind with water that has gone by.

The next thing after reclaiming this truant energy by means of this machinery is to deliver it to the people who want it, and first of all we must carry it to the switchboard. The switchboard is always the first link between a power-house or central station and the outside world. To it generally lead the current conductors of all the dynamos; from it start, and to it return, all the smaller conductors and wires that deliver the current to lamps, motors and other devices.

* A lecture delivered before the Franklin Institute, January 3, 1896.

It is provided with switches which enable you to put one dynamo in connection with all the circuits of your customers, or all the dynamos if necessary, on one circuit. With these switches when you open one circuit you automatically close another, and in short, you can make so many changes with one turn of a little handle, that what happens may well be compared to the old-fashioned game of "General Post." The switchboard is, in fact, a clearing-house, a warehouse, a big retail store that receives its goods wholesale and instantaneously splits them up for consumption. Besides doing all this, it serves to protect the apparatus from lightning and sudden shocks, and by means of tell-tale instruments placed on it, you can see at once how everything is going, whether the dynamos are running properly and whether the customers are getting all the current they want and of good quality. Now, in almost all places, the switchboard is a tall wall or slab of marble or mahogany, not unlike a big front door with lots of knobs, knockers and keyholes on it; but at the Niagara power-house it takes the form of an imposing altar or tomb—perhaps we might call it a local option platform, or, having in mind its controlling functions, we may compare it to the bridge of an ocean steamer, while the man in charge or handling the wheels answers to the navigating officer.

The ingenious feature is employed of using compressed air to aid in opening and closing the switches. The air comes from a compressor located at the wheel-pit, and driven by a small water motor. It supplies air to a large cylindrical reservoir, from which pipes lead to the various switches, the pressure being 125 pounds to the square inch. So far as the main switches are concerned, every electrical engineer will realize that it is a serious thing to manipulate a dynamo circuit loaded with 5,000 horse-power of current. It is comparable to changing front right about face with a headlong charge of a squadron of heavy cavalry. It appears, however, to be done very successfully and quietly by the mechanism shown. Another interesting point is, that the measuring instruments on the switchboard do not measure the whole current, but simply a derived portion of

determined relation to that of the generators. In other words, the operator on the platform cannot touch a dangerous circuit, and he simply acts as a sampler or taster, much as one does who tests with tube the purity of Croton water or digs a gouge into a big cheese. All told, less than one-thirtieth of a horse-power gives him all the indications required. To the switchboard current is taken from the dynamos by heavy insulated cable, and it is then taken off by huge copper bus bars, which are carefully protected by layers of pure Para gum and vulcanized rubber, two layers of each being used, while outside of all is a special braided covering, treated chemically to render it non-combustible. The calculated losses from heating in a set of four bus bars carrying 25,000 horse-power, or the total output of the first

Main power-house and transformer house.

five Niagara generators, is only 10 horse-power. The cables and bus bars are mainly the work of Mr. W. M. Habirshaw, one of our leading manufacturers of insulated wires and cables.

Those who have not a very definite idea of the insulation by which a current is cribbed, cabined and confined within its proper channel, the copper, can arrive at a clear understanding of it from this cable, of which about 1,200 feet were supplied for the power-house. It has not broken down until between 45,000 and 48,000 volts of alternating current were applied to it, which will show that the insulation is a pretty effectual strait-jacket. There are 427 copper wires in that cable, consisting of 61 strands, laid up in reverse layers, each strand consisting of 7 wires. Next to the strand of copper is a wall of rubber, $\frac{1}{4}$ inch thick,

double coated. Over this is wrapped absolutely pure rubber, imported from England, and known as cut-sheet. Then come two wrappings of vulcanizable Para rubber, answering, we will say, to shirt and trousers. Then there is a wrapping of Poole-made cut-sheet, and on top of that are two more rubber coats. This is then taped, covered with a substantial braid and vulcanized. The object in using the cut-sheet is to vulcanize it by contact, in order to make it absolutely water-tight. This cable weighs just over 4 pounds to the foot, of which 3 pounds are copper and 1 pound insulation.

We have thus advanced far enough to get our current on to the bus bars, and the next step is to get it from them out of the power-house. This final work we do by simply extending our bars, so to speak, and carrying them across the bridge, over the canal, into what is known as the transformer house, that quiet little place resembling a porter's lodge at the gate of a mansion. It is here that the current received from the other side of the canal is to be raised in potential so that it can be sent great distances over small wires without material loss, for that is one of the purposes underlying all the plans of the Cataract Construction Company. We shall touch on this presently. Meantime, we may note that the Niagara Falls Power Company itself owns more than a square mile around the powerhouse, upon which a large amount of power will be consumed in the near future by manufacturing establishments of all kinds, and that it is already delivering power in large blocks, electrically, to one factory for the production of aluminum, and to another for the production of the remarkably efficient abrasive called carborundum, an improved kind of emery, for which a great many uses are being found. Special apparatus for this work has been built by the General Electric Company. The current for the production of aluminum is made direct by passing through static and rotary transformers, while the Acheson carborundum process uses the pure alternating current. Besides this, the trolley road from Niagara to Buffalo is taking already part of its power from the Niagara power-house by means of

rotary transformers. For these and other local uses the company has constructed subways in which to carry the wire across its own territory. These subways are 5 feet 6 inches high, and 3 feet 10 inches wide inside. They are built up with 12 inches of Portland cement and gravel, backed up with about 1 foot of masonry at the bottom and extending about 3 feet up each side. The electric conductors are carried on insulated brackets or insulators arranged upon the pins along the walls. These brackets are 30 feet apart. At the bottom of the conduit manholes are holes for tapping off into side conduits, and along it all runs a track upon which an inspector can propel himself on a private trolley car, within screens, if necessary. Thus is distributed locally the electric power for which the consumer pays the very modest sum of $20 per electrical horse-power per annum, delivered on the wire, or $12 for a turbine horse-power, a rate which is not to be equalled anywhere,* I imagine, in view of the absolute certainty of the power, free from all annoyance, extra expense, or bother of any kind on the part of the consumer. This is why industries of all kinds needing power in substantial quantities are beginning to flock to Niagara.

But there is a converse aspect of this power question. While on the one hand the power attracts customers, on the other hand there are many places and many customers that would rather have the cheap power brought to them. This is a fact we are all familiar with in many spheres of life and labor. Some Europeans have come to this country, but for the vast majority our cheap wheat and beef must be taken to them. Some cotton mills exist in the South, but the bulk of the cotton must be carried to New England or old England. Some coal is burned near the pit's mouth, but the largest part goes far from the beds yielding it. All this is for the reason that in so many cases it is cheaper and better to take power to the people than to bring the people to the power. Now, Buffalo and Rochester and Albany

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* This is where the power is developed by the tenant himself, *i. e.*, the tenant putting in his own hydraulic machinery and water connections.

need power in large quantities, but obviously it is advantageous for many reasons to give them cheap power where they are, rather than bring them to Niagara, and if this can be done, it is just as though Niagara itself were in their precincts, instead of being scores or hundreds of miles away. If the power is in the shape of wheat and beef, we need ocean steamers; if it is coal, we need tracks and locomotives; if it is electricity, all we need is a fine wire, so slim that at a distance of 200 or 300 yards you could not possibly see it.

It is a curious fact that the proposal to transmit the energy of Niagara a long distance over a wire should have been regarded with so much doubt and scepticism, and that the courageous backers of the enterprise should have needed time to demonstrate that they were neither knaves nor fools, but simply brave, far-seeing men. We have to-day parallel instances to Niagara in the transmission of oil and natural gas. Oil is delivered in New York City over a line of pipe which is at least 400 miles long, and which has some thirty-five pumping stations *en route*, the capacity of the line being 30,000 barrels a day. All that oil has first to be gathered from individual wells in the oil region and delivered to storage tanks with a capacity of 9,000,000 barrels of oil. Chicago, Philadelphia and Baltimore are centers for similar systems of oil pipe, running hundreds of miles over hill and dale. Now, how improbable such a plan would have seemed if propounded at the beginning of this century to the plain captain of a New Bedford whaler. As for natural gas, that is to-day sent in similar manner over distances of 120 miles, Chicago being thus supplied from the Indiana gas fields, and the gas has its pressure raised and lowered several times on its way from the gas well to the consumer's tap, just as though it were current from Niagara.

We must not overlook some of the fantastic schemes proposed for transmitting the power of Niagara before electricity was adopted. One of them was to hitch the turbines to a big steel shaft running through New York State from East to West, so that where the shaft passed a town or factory, all you had to do was to throw on a belt or some

gear-wheels and thus take off all the power you wanted. More reasonable, though, perhaps, not much less infinitely expensive, was the plan to have a big tube from New York to Chicago, with Niagara Falls at the center, and with the Niagara turbines hitched to a monster air compressor, which should compress air under 250 pounds pressure to the square inch in the tube. As under the other plan, all you had to do, if needing power, was to tap this compressed air tube and get what you wanted. But Niagara certainly was not destined to blow her own trumpet in that longitudinous way.

So far as actual electrical long-distance transmission from Niagara is concerned, it can only be said to be in the embryonic stage, for the sole reason that for nearly a year past the Power Company has been unable to get into Buffalo, and that not until recently has it been able to arrive at acceptable conditions, satisfactory alike to itself and to the city. Work is now to be pushed at once, and, in less than a year, power from the Falls will be in regular delivery to the local consumption circuits at Buffalo, 22 miles away. For the transmission of the first 10,000 horse-power to Buffalo it has been decided to use the pressure or potential of 10,000 volts, with such arrangements at each end that 20,000 volts can be used if necessary. There will be no difficulty about this work. The company has carefully secured rights of way for its pole lines, and the conditions have already been dealt with in other places, as many of you are aware. The 105 miles transmission from Lauffen to Frankfort, in 1891, was at the pressure of 40,000 volts. Many mines in this country, up in the mountains, now have their power brought to them over miles of line. From the San Antonio Cañon, in Southern California, electric power, generated by the melting snows of the mountains, is sent at a potential of 10,000 volts to San Bernardino, nearly 30 miles away, for both light and power. At Guadalajara, Mexico, the General Electric Company has a transmission circuit of 18 miles and 11,000 volts; and it has another at Pachuca, under construction, of 23 miles. A famous high-voltage, alternating-current transmission in Europe is that from the

Falls of Tivoli, on pole lines, to Rome, a distance of 17 miles. This year has witnessed the celebration, by the city of Sacramento, Cal., with beating of drums, firing of cannon, street parades, per-fervid oratory and lavish illuminations, of a transmission of power at 11,500 volts from Folsom, 23 miles away. Salt Lake City is now to be supplied with power from eight lakes up in the famous Wahsatch Mountains. It will be seen that the Buffalo problem is well within easy handling, and, with growing knowledge and better apparatus, the conditions for such work improve all the time. For example, the circuits are carried by triple-petticoated insulators of porcelain, and these are now cured to withstand a pressure of 90,000 volts before a puncture can be made. In short, a line efficiency between Niagara and Buffalo of at least 90 per cent. is looked for, so that for every 10,000 horse-power passed into the step-up transformer on the brink of the canal at Niagara, 9,000 horse-power will be taken off by the step-down transformers in the receiving station at Buffalo. It is also believed that the power can similarly be sent to Albany, on poles along the Erie Canal, at a loss of about 60 per cent., so that 10,000 horse-power at Niagara would represent 4,000 horse-power available for distribution at the junction of the Erie with the Hudson, 300 miles away.

But the question arises, and has been fiercely discussed, whether it will pay to send the current beyond Buffalo; whether it is worth while to reach out to Rochester, Syracuse and Albany; whether, in fact, it is even worth while to take it to Buffalo, the center of cheap coal, cheap oil and cheap natural gas. I, for one, cannot help thinking that Niagara power will compete favorably with other power in Buffalo; for recent official investigations, made by Mr. H. A. Foster, have shown that steam-power in large bulk, under the most favorable conditions, costs to-day in Buffalo $50 per year per horse-power, and upwards. Evidently, Niagara power, starting at $10 on the turbine shaft, or, say, $18 on the line, has a good margin for effective competition with steam in Buffalo.

Now, as to the far-away places. The well-known engi-

neers, Prof. Houston and Dr. Kennelly, have made a most careful estimate of the distance to which the energy of Niagara could be economically transmitted by electricity. Taking established conditions, and prices that are asked to-day for apparatus, they showed that even in Albany or anywhere else in the same radius—330 miles from the Falls—the converted energy of the great cataract could be delivered cheaper than good steam-engines on the spot could make steam-power with coal at the normal price there of $3 per ton. I do not now propose to go into controversy or details, but I do make bold to say that when such conclusions are reached and find support, the time is certainly on us when we must deal with these long transmissions of electrical energy as new factors in the industrial commercial life of the State and nation.

You must have been impressed with the fact shown in this brief running comment on the situation, that what this enterprise at Niagara aims to do is not to monopolize the power, but to distribute it; and that in this way it makes Niagara more than it ever was before, the common property of the citizens.

After all is said and done, very few of us ever see the Falls, and then only for a chance holiday once in a lifetime; but now the useful energy of the cataract will be made cheaply and immediately available, every day in the year, to hundreds and thousands, even millions of people, in an endless variety of ways. If this be not to make Niagara a common heritage, then I do not know what the phrase means.

Perhaps some of you remember the story about Miss Porter, a member of the family that was once in possession of the Niagara region. She was traveling in Europe, and at dinner one night her companion said: "Oh, if you are an American, I suppose you have seen Niagara Falls." She turned on her escort haughtily, and fixing a stony glance on him, said: "I own them." We can now all say with Miss Porter: "We own them."

We must not omit from our survey the Erie Canal, in the revival and greater utilization of which, as an important

highway of commerce, Niagara power is expected to play no mean part. In competition with the steam railway, canals have suffered greatly the last fifty years. In our own country, out of 4,468 miles of canal built at a cost of $214,-000,000, about one-half has been abandoned, and not much of the rest pays expenses, which is what you might expect when you race a mule barge against a fast freight train. Yet canals have enormous carrying capacity, and a single boat will hold as much as twenty freight cars can, so that obviously if you give the canals cheap, good power, you can do for them what has now been done for the street car lines by devoting the horses to the canning industry. In other words, give the canals cheap electric power and we shall again have them a powerful factor in the equalization and minimizing of freight rates. I am glad to say that this has already been recognized by our own State authorities, who have agreed to conditions by which Niagara energy can be used to propel the canal boats at the rate of $20 per horse-power per year. Where steamboat haulage for 240 tons of freight now costs about 13 cents a boat mile, it is estimated that electric haulage will cost not to exceed 10½ cents, while, with the energy from Niagara at only $20 per horse-power per year, it will cost much less. Evidently this is a task worth attempting. Some two years ago the first attempt was made in this country and on the Erie Canal, with the canal boat *F. W. Hawley*, when the trolley system was used with the motor on the boat, as it is on an electric car, driving the propeller as if it were the car wheels. But the better and cheaper way is to modify the plan of hauling your boat from the tow-path, and this is what is now being done with the electric haulage system of Mr. Richard Lamb on the Erie Canal at Tonawanda, near Niagara. Imagine an elevator system working lengthwise instead of vertically, and you will get a rough idea of the arrangement. There is placed on poles a heavy fixed cable on which the motor truck rests, and a lighter traction cable is also strung, that is taken up and paid out by a sheave, as the motor propels itself along, and pulls its canal boat to which it is attached. If boats come from opposite direc-

tions they simply exchange motors, just as they might mules or locomotives, and go on without delay. There is no reason why the whole of the Erie Canal should not be equipped this way for freight, and if the canal be deepened, a so much higher rate of speed can be obtained that it might even pay poor people to travel again by canal boat as it once did our grandfathers and fathers. I can imagine worse traveling experiences than a trip along the picturesque Erie without dust or smoke, at the rate of 5 or 6 miles an hour on the broad deck of a comfortable "canal greyhound."

We might digress on many such pertinent and allied themes; as, for example, the operation of the New York Central Railroad by electric power from Niagara, but must leave them, not only for the present moment, but also for the coming years, which alone can show all the wonderful possibilities of this noble, and, I am firmly convinced, profitable enterprise. Before I close there are two other points, however, to which I ought to direct attention. One is to the fact that, on its property at Niagara, the power company has already begun the development of the new village, called Echota, a pretty Indian name, which signifies "Place of Refuge." I believe it is Mr. Howells who, in kindred spirit, speaks of the "repose" of Niagara. It was laid out by Mr. John Bogart, the New York State engineer, and embodies all that is best in sanitation, lighting and urban comfort. That which was waste wilderness blossoms as the rose, not figuratively, but literally, and it does not need the eye of faith to see here the beginning of that which is destined to be the beautiful center of one of the busiest, cleanest, prettiest and healthiest cities in the Union. The workingman, whose factory is not poisoned by smoke and dust, whose home was designed by McKim, Mead & White, whose streets and parks were laid out by distinguished engineers, and whose leisure is spent within sight and sound of lovely Niagara, has little cause for grumbling at his lot.

My final comment is upon the interesting strategy with which our American company has also pre-empted the great

utilization of the Canadian share of Niagara's energy. Thus far I have dealt only with the work done and contemplated on our own side of the river, but I now show you the plan approved by the Canadian Government for the company's work on their side. This plan, not yet carried out, proposes the erection of two power-houses of a total ultimate capacity of 125,000 horse-power. Each power-house is fed by its own canal, and is, therefore, an independent unit. Owing to the better lay of the land, the tunnels carrying off the water discharged from the turbines will have lengths, respectively, of only 300 and 800 feet, thus avoiding the extreme length and cost unavoidable on our side. In one of the designs it has been suggested to put the dynamos underground alongside the turbines, at the bottom of the shaft; but I hardly think that this damp, rheumaticky, but ingenious scheme will be adopted. With both the Canadian and the American plants fully developed, no less than 350,000 horse-power will be available, while the stationary engines now in use in New York State represent only 500,000 horse-power. Yet the 350,000 horse-power are but one-twentieth of the 7,000,000 horse-power which Professor Unwin has estimated the Falls to represent theoretically. If the 350,000 horse-power were estimated at $20 per year per horse-power, and at Niagara should replace the same amount of steam-power at $50, the annual saving for power in the State would be more than $10,000,000 per year—an accomplishment that within a very few years may give Niagara a stronger claim to the admiration of the Empire State than it has ever had before.

Let me not transgress any longer on your time and attention with diagrams and data, but once more, by way of conclusion, emphasize the truth that this splendid engineering work leaves all the genuine beauty of Niagara untouched. It may even help to conserve the scene as it exists to-day, for the terrific weight and rush of waters over the Horse-shoe Fall is eating it away and breaking its cliff into a series of receding slopes and rapids; so that even a slight diminution of the whelming mass of wave

will, to that extent, lessen disruption and decay.* But be that so or not so, those of us who are lovers of engineering can now, at Niagara, gratify that taste in the unpretentious place where some of this vast energy is reclaimed for human use, and then, as ever, join with those who, not more than ourselves, love natural beauty, and find with them renewed pleasure and delight in the majestic, organ-toned and eternal cataract.

[The lecture was profusely illustrated with stereopticon views.]

A PRACTICAL PLAN FOR SAND FILTRATION IN PHILADELPHIA.

By Allen Hazen, C.E.

[*A report to the Woman's Health Protective Association of Philadelphia.*]†

In accordance with your instructions I have examined the water-works system of Philadelphia, to determine whether or not it is feasible to purify the water of that city by means of sand filtration as commonly practiced in Europe, and without the use of alum or other coagulants, and if so, to determine as nearly as may be what cost would be thereby involved.

I wish to acknowledge at the outset my very great obligation to Mr. John C. Trautwine, Jr., Chief of the Water Bureau, who has placed the resources of his office at my disposal, and without whose co-operation this report would have been impossible. I am also indebted to Mr. Amasa Ely, his assistant, for personal attention in examining the various grounds mentioned in this report, and to other gentlemen of the Water Bureau for their uniform courtesy and attention in furnishing maps, statistics and data at their disposal.

* Professor Shaler, of Harvard, has suggested the buttressing of the cavities under the falling sheet of water, with masonry, so as to hold up the superincumbent strata.

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The question of filtering the water supply of Philadelphia has already been considered at the direction of your Association, by Joseph B. Rider, C.E., who presented a report thereon, dated April 29, 1895. Mr. Rider advocated the adoption of some form of sand filtration, but was inclined to favor a plan somewhat at variance with the most approved European practice.

In the short time available for this examination it has been possible to make but a superficial examination of the problem, sufficient only to determine the feasibility of the general process suggested; and this report, so far as it relates to particulars of arrangement of works, etc., must be considered as suggestive rather than in the nature of definite recommendations.

This is particularly the case, as the whole subject of future water supply for Philadelphia was most exhaustively considered by Mr. Rudolph Hering, an engineer of great eminence and ability, during the years from 1883 to 1886; and as a result of his studies he recommended to the city the introduction of water by gravity from upland sources, supplemented by water pumped from the Delaware River from a point above the most serious points of pollution. Mr. Hering did not consider at length the filtration of the present sources, as he did not consider the then existing evidence as sufficient that filtration would adequately purify such waters. The additions to our knowledge of the nature and results of filtration during the last ten years have materially changed the aspects of the case, and Mr. Hering has himself indicated that if he were reconsidering the subject he would give serious attention to the filtration of the present supply.

The advantages of a gravity supply from upland areas, where the water is not subject to pollution by sewage, are very great, and the project recommended by Mr. Hering is not to be put lightly aside to make room for the latest ideas concerning the purification of polluted waters obtained from sources near at hand, and you will thus readily understand that it is impossible for me at this time to recommend the adoption of any system. I have simply canvassed the

ground in a preliminary way to determine the possibilities of filtration.

In case the city should take the matter up, it would be desirable and necessary to have the various suggested localities surveyed and examined by test pits, and to have plans prepared for the various works involved. It would probably be found, upon further study, that the general plans here suggested could be modified with advantage in many important particulars, and a plan could be worked out which could be taken as representing the most favorable system of filtration. This plan should then be compared in all its phases with the plan recommended by Mr. Hering, taking into account changes in the cost of construction and of the interest to be paid for borrowed money, etc., which may have occurred in the ten years since Mr. Hering's report; and it would be only after such a comparison, which is quite beyond the scope of the present report, that a reliable opinion as to the expediency of the introduction of filtration could be given.

PRESENT SOURCES OF SUPPLY.

The city of Philadelphia now derives its water from the Delaware and Schuylkill Rivers, 94 per cent. being taken from the Schuylkill and 6 per cent. from the Delaware. The Schuylkill above the intakes has a drainage area of 1,900 square miles, and the population upon the water-shed above Philadelphia in 1890 was about 350,000, or 185 per square mile. The most important points of pollution are as follows:

Town.	*Population. (Census of 1890.)*	*Distance above intake. Miles. (Queen Lane.)*
Conshohocken	5,470	8
Norristown	19,791	12
Phœnixville	8,514	23
Pottstown	13,285	39
Reading	58,661	60
Pottsville	14,117	103
Total	119,838	

Urban population on water-shed, 63 per square mile.

An effort is now being made to treat and purify the sewage of Reading before its discharge into the river; but there is no assurance that this treatment as yet is adequate. Aside from Reading, all sewage produced upon the watershed is discharged directly into the streams.

The water from the Schuylkill for Philadelphia is pumped from two pools formed in the river by dams within the limits of the city. The sewage from portions of the city was formerly discharged into these pools. An intercepting sewer has been constructed, which takes sewage to a point below a dam below the lowest pumping station. The district served by this intercepting sewer is sewered by what is known as the separate system. That is to say, the rain water and sewage are removed by separate systems of carriers, and I am informed that little, if any, sewage is discharged from the city sewers at any time into the river above the intakes. The river banks above the city limits, and the west side of the river, where the latter forms the boundary, directly opposite the city, are occupied by manufacturing establishments discharging directly into the river.

The use of water from the Schuylkill at the present intakes has been regarded by every competent authority investigating the subject for many years as most objectionable, and the use of water from such a polluted source should be abandoned at the earliest possible moment.

The Delaware River above the water-works intake has a drainage area of 8,100 square miles, with a population in 1890 of about 600,000, or 74 per square mile. The most important places which may pollute the river are as follows:

Town.	*Population.* (*Census of 1890.*)	*Distance above intake. Miles.*
Burlington, N. J.	7,264	11
Bristol, Pa.	6,553	12
Mount Holly, N. J.	5,376	15
Bordentown, N. J.	4,232	21
Trenton, N. J.	57,458	26
Lambertville, N. J.	4,142	41
Point Pleasant, Pa. (Point suggested by Mr. Hering as source of water for Philadelphia)		50

Phillipsburg, N. J.	8,644	75
Easton, Pa.	14,481	75
South Easton, Pa.	5,616	76
Bethlehem, Pa.	6,762	86
South Bethlehem, Pa.	10,302	86
Allentown, Pa.	25,228	91
Mauch Chunk and East Mauch Chunk, Pa.	6,873	121
Hazleton, Pa.	11,872	140
Port Jervis, N. Y.	9,327	140
Total	184,130	
Square miles of water-shed		8,100
Urban population per square mile		23

The Delaware River is tidal as far as Trenton. The rise and fall at the intake is said to be about 6 feet. Most of the city sewage is discharged 4 miles or more below the intake; but Frankford Creek, only 1 mile below, receives a large amount of sewage, which flows with it into the river, and a number of sewers serving local population discharge very near, and even above, the intake. It is thought that at ordinary stages of the river, the flow is sufficient to prevent the tide from carrying sewage matters up stream for any considerable distance, but when the natural flow of the river is small, the up-stream movement of the river must be considerable.

I consider it desirable that the intake should be carried far enough up river to be above the highest point to which considerable quantities of sewage from the Philadelphia sewers may be carried by the tide. Whether the present intake fulfils this condition or not could be determined by numerous float experiments, and particularly by repeated bacterial examinations of the water from various points in the river, particularly at times of spring tide and of minimum flow of the river. Such examinations have not been made, but are desirable at as early a date as practicable, to determine the best location for works.

Aside from this possible tidal pollution, the Delaware River is much less polluted than the Schuylkill; its flow is greater; its water is softer; it is less subject to local pollution, and, in every way, it is more desirable as a source of water supply than the Schuylkill; and the same is equally

true whether the waters of each are used in their raw condition, as at present, or if each of them should be filtered by equally good systems of filtration.

SITES FOR FILTERS.

In general topography the land upon which the city of Philadelphia is built rises gradually from the Delaware River. The Schuylkill River cuts through the highland back from the Delaware, and has but a narrow valley. The various pumping stations upon the Schuylkill are surrounded by abrupt hills, and, with but few exceptions, there are no opportunities for the construction of sand filters near them. The exceptions mentioned are not important; for, while considerable quantities of water might be filtered upon land immediately adjoining the Queen Lane and Belmont pumping stations, the areas are inadequate for the filtration of the quantities which will be required for supplying the respective districts, and it will be better to establish filters at other points where all the areas necessary in the respective cases are available at one point.

While the river bottom furnishes no adequate sites for filters, such sites can be found upon the higher and comparatively flat land a short distance back from the river. In utilizing such sites the force mains from the pumping station would be taken to filters constructed upon land above and near the respective reservoirs, and at such elevations as to necessitate as little extra pumping lift as possible. The water would be filtered and then drained from the filters into the respective reservoirs.

At Belmont an area of land a little higher than the reservoir is available, great enough for all possible requirements. A part of this area is park property, while a part is agricultural land and could probably be secured by the city upon reasonable terms.

The Fairmount pumping station, and the Fairmount, Corinthian and Spring Garden reservoirs, are in a closely built-up portion of the city, and are surrounded by lower ground, so that no suitable sites for filters are available in their immediate vicinity.

An area of land between Lehigh Avenue and Clearfield Street, and between Twenty-eighth and Thirty-first Streets, and extending for a little beyond the latter, is owned by the city, having been purchased as a reservoir site. The reservoir, which was to have been called the Cambria reservoir, has not been, and probably will not be, constructed, as the Queen Lane reservoir, in a measure, takes its place. The city owns 45 acres of land in this place, suitable for filter sites, and an additional area immediately adjoining it is now used for agricultural purposes, and could probably be secured. Filters constructed upon this land could be reached from the Spring Garden pumping station, and also, if necessary, from the Queen Lane pumping station, and the effluent would be at a sufficient elevation to drain into the largest of the city reservoirs, the East Park reservoir. The land now owned by the city is sufficient to allow the construction of filters with an effective filtering area of 30 acres with all accessories, and with a maximum filtering capacity of 90,000,000 gallons per day, and with the purchase of other suitable land this capacity could be increased at least one-third.

Another available site for filters is found above the Queen Lane reservoir, where, without going beyond School Lane and Wissahickon Avenue, an area is available sufficient to allow the construction of filters with an effective filtering area of 40 acres, and with a maximum capacity of 120,000,000 gallons per day.

Still another and higher site for filters is available north of the new Roxborough reservoir. I have not maps to show the exact area of this tract, but it is certainly sufficient to meet any reasonable requirements for a long period of years.

Along the Delaware, at the Frankford pumping station, and for many miles above upon the river bank, there are excellent and ample sites for filters. To utilize these sites filters might be constructed in excavation below the level of the river, but it would probably be better to construct filters upon the natural river bank, at an elevation of from 10 to 20 feet above tide water, and to raise the water from the river

by means of centrifugal or low-lift pumps. The filtered water would then flow to the present pumping engines, and be pumped by them as at present, and, if additional capacity should be required, by others, to the various reservoirs, or directly into the pumping mains.

SYSTEM OF DISTRIBUTION.

I have not had time to study in detail the system of distribution in Philadelphia, nor is such a study essential to the direct purpose of this report. The following suggestions as to a revised arrangement of districts are based upon the report of the Bureau of Water for 1891, where a proposed future system is outlined.

The first, or Belmont district, comprises that part of the city west of the Schuylkill River, has an area of 21 square miles, and is supplied from the Belmont pumping station upon the Schuylkill River. The estimated population in 1890 was 100,000.

The second, or Roxborough district, is east of the Schuylkill River, and comprises that part of the city above an elevation of 165, city datum. It has an area of 23 square miles, and had a population in 1890 of 70,000, and is supplied from the Roxborough pumping station. At the present time the Roxborough pumping station is supplying a larger area and population because water is let down from it to lower levels; but as this involves pumping of the water to an unnecessary height, it will be desirable to shut off these lower areas and to supply them from the Queen Lane reservoir as soon as the latter is ready for full use.

The third, or Queen Lane district, comprises land on the east side of the Schuylkill, more than 60, but less than 165 feet above city datum, but not including the higher parts of what may be called the Frankford district. This third district, which is in part—and will soon be entirely—supplied from the Queen Lane Reservoir, has an area of 18 square miles, and its population in 1890 was 208,000. The remaining 29 square miles of high land in the city, most of which is agricultural land, and having as yet only a slight

population, need not be considered further at the present time.

The fourth district includes all that part of the city below the level of 60 feet, city datum, and is now supplied by the Fairmount and Spring Garden pumping stations, and from the Frankford pumping station (the latter including land up to a level of 90); it covers 38 square miles, and had a population in 1890 of 670,000. This is by far the largest part of the city, and is capable of being supplied either from the Schuylkill or the Delaware, or, as at present, from both. The three first mentioned districts, that is, Belmont, Roxborough and Queen Lane, are much more readily supplied from the Schuylkill than from the Delaware.

The rather numerous high-service districts served by secondary pumpage are not here considered, as securing a pure water at the primary stations involves supplying the same to all secondary systems dependent upon them.

To supply the district below 60, city datum, with filtered water, it will be possible, as mentioned above, to filter the water from Spring Garden station on the site proposed for the Cambria reservoir, and to filter the water pumped at the present Frankford pumping station through filters in its immediate vicinity, or it may be better to go to a point further up the Delaware and construct a new pumping station and filters upon a site particularly adapted to them, and to pump the water from this point into the mains supplying the lower part of the city.

RESERVOIRS.

The city of Philadelphia is supplied with water from elevated reservoirs filled from the rivers by pumping. That is to say, the water pumped is carried direct to reservoirs, and the reservoirs are connected with the system of pipes leading to the consumers. At the present time there is an exception to this arrangement in that water for a small part of the city is pumped directly into the mains from the Spring Garden pumping station; but this is a temporary condition, which will not be continued after the Queen

Lane pumping station and reservoir are ready for full service.

The objects accomplished by these reservoirs are two-fold: (1) they assure an abundant quantity of water at all times; and (2) the storage improves the quality of the water supplied. In so far as they relate to quantity, they serve to balance the fluctuations of consumption during the different hours of the day, so that the pumps can be operated at a constant rate while the consumption fluctuates from hour to hour; and they also serve as a reserve to supply the city in case of breakage or other accidents to the pumping machinery or mains, or for use in case of unusual conflagration or other excessive demands.

In so far as the reservoirs serve to balance the different rates of consumption at different hours of the day (and this is one of their most important functions), the reservoirs at Philadelphia are very much larger than is necessary. The city has eleven considerable reservoirs, with an aggregate nominal capacity of 1,400,000,000 gallons, equivalent to six or seven days' supply at the present rate of consumption. Several of the reservoirs, however, are not in condition for full service, and the actual quantity of water held in reserve does not exceed 1,000,000,000 gallons, or five days' supply, while reservoirs with an available capacity of one-half of one day's supply are ample to balance the hourly fluctuations in consumption.

In regard to the necessity of maintaining so large a quantity of water for emergencies, it might be well to mention that the water-works in many large cities, including such cities as Detroit and Indianapolis, are operated without any reserve whatever of this nature, the water being pumped directly into the mains as required, without storage. It is necessary in such cases to provide a pumping capacity considerably in excess of the actual maximum consumption, to allow for accidents to any part of the machinery, and practical experience has demonstrated that, with reasonable precautions, it is possible at all times to maintain an adequate supply. As a rule, and within certain limits, additional pumping machinery is cheaper than additional reser-

voirs, and the advisability of maintaining so large reservoir capacity, simply with reference to maintaining the quantity of the supply, may be seriously questioned.

The second function of the reservoirs, perhaps even more important than the first, is that of improving the quality of the water. All the water, with the above-mentioned exception, is pumped to the reservoirs, and it ordinarily remains in them for several days. During these days much of the mud contained in the water is removed by sedimentation; although, after heavy storms, the water supplied from the reservoirs is often very muddy; and, judging from the experience of other cities, and by tests of Dr. Bolton of water from the East Park reservoir, the greater part of the bacteria are also removed, in part by sedimentation, and in part by death, as the conditions in reservoirs are not favorable for the propagation of pathogenic germs, and the larger the reservoir the greater the improvement thus effected. If Philadelphia had reservoirs many times as large as the existing ones, and were able to use them in rotation, it is probable that a reasonably pure, or even an entirely satisfactory, water could be secured from them, even from the present polluted sources; and if the reservoirs had been smaller than they are, the city would have suffered much more severely than it has from the evils of contaminated water. From this standpoint, the ample reservoirs are extremely fortunate and none too large.

In case pure water is furnished, by filtration or otherwise, the conditions with reference to the city's reservoirs will be radically changed. The water will not then be further purified in the reservoirs, and there will be no object in pumping all of the filtered water first to the reservoirs; but it will be quite as satisfactory to pump the water directly into the mains and allow it to go direct to the consumers. By connecting these mains with the present reservoirs it will be possible to operate the pumps at a constant rate, as it is always desirable to do. When more water is pumped than used, as during the night, the excess will go to the reservoirs, gradually filling them; while during the day hours of heavy consumption, when more water is used than is

pumped, the excess pumped during the previous night will be available from the reservoirs to supply the deficiency. The reservoir capacity needed to maintain this service need not necessarily exceed one-third or one-half of one day's supply.

Algæ growths, dependent upon sunshine, are much more abundant in pure water than in ordinary river waters, and, in case the supply is filtered, it will be a serious question whether it will not be desirable to cover the reservoirs by roofing or otherwise, so far as they are directly connected with the distributing system. The necessity of covering would be equally great with any system of filtration—with mechanical filtration as much as with sand filtration. Lawrence and Poughkeepsie, supplying filtered water, use open reservoirs, but a certain amount of algæ growths results. This growth is not particularly unhealthy, but it sometimes becomes disagreeable to the senses.

CONSUMPTION OF WATER.

The population in Philadelphia for 1895, assuming that the increase was at the same geometric rate as it was from 1880 to 1890, was 1,164,000; and the quantity of water pumped, as shown by the pumping records, was 77,819,013,-610 gallons or 212,760,673 gallons per day, or 183 gallons daily for every person in the city. In the report of the Water Bureau for 1895 is given a somewhat larger estimate of the population, and a correspondingly lower estimate for the consumption per capita, namely, 162 gallons. Whichever estimate is correct, it is only possible to agree most heartily with the present able Chief of the Water Bureau and with his predecessors, and with every one who has seriously considered the matter in recent years, that this consumption is excessive and entirely beyond the reasonable requirements of the city, and it should and could be reduced at once, by proper measures, to a very much lower figure, probably one-half of the present consumption. It is often alleged that the increased use of baths and other domestic arrangements requiring water largely increases the consumption, and that the rapid increase of manufacturing operations demands

large quantities of water, and that the increase in consumption is to be accounted for in these ways.

The most careful studies show, however, that even in the best class of modern houses, with the most liberal number of fixtures, with reasonable use of water, the consumption does not exceed 30 gallons per capita, or one-sixth of the present consumption in Philadelphia. The demands for water for manufacturing purposes, although undoubtedly larger than formerly, are inadequate to account for the alarming increase in consumption. This increase can only be accounted for by the deliberate or careless waste of water due to a wrong method of charging for the same.

Consider, if you please, what would happen to the city gas works if bills were collected according to the size of the house and the number of fixtures, the charge being the same whether gas was used in an economical and modern manner or whether every jet was lighted and allowed to burn all night, and all day long, too, for that matter. You will see that with such a system gas would be deliberately wasted on every hand and the consumption would increase to several or many times the normal and proper amount. As the works would not be operated at a loss the rates would be raised to cover the needless use of gas, and would be much higher than would be necessary under economical conditions. This condition of affairs is so absurd that it is difficult to give it serious consideration; but it is precisely what is being done in the Water Department in spite of the urgent protests and appeals of the present Chief and of his predecessors for the substitution of a more rational and business-like basis.

The remedy for this most unfortunate condition of affairs is simple, and consists in adopting the same principles in the sale of water that are already followed in the sale of gas. Every water service should be metered, and the quantity of water used charged for at a rate sufficient to pay for its collection, purification and distribution; and when this is done I venture to predict that your consumption will be reduced one-half; that everyone will have water in abundance, and that all persons except those who are now drawing

water largely in excess of their legitimate demands will be served at a less cost than at the present time. The advantages of this arrangement are so obvious, and will accrue with such uniformity to all parties involved, that it seems incredible that the waste of water has been allowed to go so far without adopting means for preventing it.

NATURE OF FILTRATION PROPOSED.

The filters which I have under consideration are the ordinary sand filters, similar to those in use at London, Hamburg, Altona, Liverpool, Amsterdam, Rotterdam and many other cities. They will consist of water-tight basins, with masonry sides and a water-tight pavement for a bottom, on which will be placed underdrains surrounded by gravel, and upon this a layer of sand. The water is to be brought over the sand by suitable devices and filtered downward through it and afterward collected by the gravel, when it will flow through the underdrains to a suitable regulating apparatus for controlling the rate of filtration and loss of head, and thence to the reservoirs or pumps.

The walls of the filters are to be constructed of solid brick masonry, or a cheaper rubble masonry might be used, lined with brick. The bottoms will require to be watertight, and can, perhaps, best be made by a thin layer of concrete, with a water-tight asphalt covering above. The pressure sustained will be very much less than in the present reservoirs, and a lighter bottom can thus be used.

Sand and gravel suitable for filtration do not exist upon or near any of the sites proposed for filters, except, possibly, sites upon the Delaware, and these materials will require to be brought in from a distance. Crushed stone can be secured at market rates, and bar or bank sand is also a regular article of commerce in Philadelphia. In the case of the construction of the filters, however, it will, perhaps, be better to have specially equipped boats or barges at the points from which sand is originally secured, provided with the necessary equipments to wash the sand and prepare it for placing in the filters, so that no waste material need be transported to the site of the filters. I examined numerous

samples of sand now being brought into the city for building purposes, and I am confident that no difficulty will be experienced in securing an abundance of sand of the quality required.

I consider that the climate in Philadelphia is not severe enough to necessitate the use of covered or vaulted filters, and I have, therefore, made my estimate for open filters. The question as to whether or not sedimentation will be necessary or desirable as a preliminary to filtration cannot be readily settled without a more extended and minute acquaintance with the qualities of the water of the two rivers. From my observations and inquiry, however, I am inclined to think that sedimentation will be unnecessary with the waters of the Delaware, although desirable with the water of the Schuylkill.

In connection with each set of filters for the Schuylkill water provision is made for a receiving basin, into which the water will be pumped and from which it will flow to the filters. These basins will hold one-fourth of a day's supply, and a considerable amount of sedimentation will take place in them, which will probably be sufficient.

The Schuylkill is ordinarily comparatively clear, and could then be filtered without preliminary sedimentation. It is only occasionally when the water is high that very turbid water is pumped, and it should be remembered that these times of turbidity will rarely, if ever, occur at the same time as the maximum consumption, and it will thus be possible to allow the filters to operate at a rate below the maximum when the water is turbid.

I assume that the average daily yield for each acre of effective filtering area for all seasons of the year, including the times when it is out of service for the purpose of being cleaned, will be 2,000,000 gallons. It is further assumed that at times of maximum consumption 50 per cent. more water will be used than the average for the year; and at such times the filters will be operated at a rate of 3,000,000 gallons per acre daily. Draughts of higher rates than this will occur for short periods only, and the deficiency at such times can be made up from the reservoirs.

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CHESTNUT HILL
FILTERING AREA
UPPER ROXBOROUGH RES.
Roxboro
LOWER ROXBOROUGH RES.
ROXBOROUGH PUMPING STA.
Mt. Airy
Mt. Pleasant
GERMANTOWN
Ashbourne
Cheltenham
Oak Lane
Rockledge
Lawndale
FRANKFORD RES.
Bustleton
Torresdale
FILTERING AREA
Holmesburg
Tacony
FILTERING AREA
FRANKFORD PUMPING STA.
FRANKFORD
Palmyra
Bridesburg
Coopersville
Wayne Jc.
Schuylkill River
W. Manayunk
MANAYUNK
FILTERING AREA
RES.
QUEEN LANE PUMPING STA.
Falls of Schuylkill
Cynwyd
FILTERING AREA
Germantown Jc.
RES.
FILTERING AREA
BELMONT RES.
PUMPING STA.
EAST PARK RES.
SPRING GARDEN PUMPING STA.
RES.
RES.
PUMPING STA.
FAIRMOUNT RES.
WEST PHILADELPHIA
DELAWARE RIVER
CAMDEN
Darby
Schuylkill River
Paschallville
GLOUCESTER
MAP OF
PHILADELPHIA
SHOWING
PRESENT INTAKES, PUMPING STATIONS
AND RESERVOIRS
TOGETHER WITH
PROPOSED FILTERS
AND CONNECTIONS.
NOYES & HAZEN,
CONSULTING ENGINEERS,
BOSTON, MASS.
AUG. 1896.
SCALE OF MILES
0 1 2 3 4 5
BRADLEY & POATES ENG'RS N. Y.

The rate of filtration is substantially the same as that actually followed in many European cities, even in cases where there is no adequate reservoir capacity and where the rate of filtration varies with the consumption. With the construction proposed such variations will be entirely unnecessary, and filtration can be maintained at a uniform rate for long periods, and under these conditions there is every reason to believe that the best results will be obtained at the rates suggested.

POPULATION AND QUANTITY OF WATER TO BE PROVIDED.

The population of Philadelphia in 1880 was 847,170. In 1890 it had increased to 1,046,946. Assuming that the increase from 1890 to 1900 is at the same rate as for the ten years before 1890, the population in 1900 will be 1,294,000. For the purpose of estimating the quantity of water required I assume that the population will be 1,300,000, and that of this number 800,000 will be resident in the low district; 260,000 will be resident in the district supplied from the Queen Lane reservoir; 100,000 in the Roxborough district, and that 140,000 people will occupy the Belmont district west of the Schuylkill River.

I have further assumed that the average consumption of water for all seasons of the year will have been reduced by the introduction of meters to 100 gallons per capita, but that at times of maximum consumption as much as 150 gallons per capita daily may be required, making a total filtering capacity required of 195,000,000 gallons. This quantity of water is much less than that now being used, but I believe it is ample for all purposes with a reasonable system for the sale of water.

ESTIMATES OF COST.

The following estimate of cost of works required to filter the quantity of water mentioned in connection with the various pumping stations has been made up from approximate data, and while not exact, the figures are upon ample basis, and will be sufficiently close to the truth for your purpose. The estimates are as follows, by pumping stations:

Belmont pumping station, 7 acres of filters; capacity, average, 14,000,000; maximum, 21,000,000 gallons daily.		
Land now owned by the city.		
Receiving basin	$35,000	
Filters	254,000	
Piping and connections	28,000	
Total		$317,000
Roxborough pumping station, 5 acres of filters; capacity, average, 10,000,000; maximum, 15,000,000 gallons daily.		
40 acres of land	$40,000	
Receiving basin	28,000	
Filters	198,000	
Piping and connections	34,000	
Total		$300,000
Queen Lane pumping station, 13 acres of filters; capacity, average, 26,000,000; maximum, 39,000,000 gallons daily.		
40 acres of land	$200,000	
Receiving basin	54,000	
Filters	472,000	
Piping and connections	61,000	
Total		$787,000
Cambria site; Spring Garden pumping station, 30 acres of filters; capacity, average, 60,000,000; maximum, 90,000,000 gallons daily.		
Land now owned by the city.		
Receiving basin	$103,000	
Filters	1,030,000	
Piping and connections	445,000	
Total		$1,578,000
Frankford pumping station, 10 acres of filters; capacity, average, 20,000,000; maximum, 30,000,000 gallons daily.		
20 acres of land	$20,000	
Centrifugal pumps and accessories for lifting water from river to filters	55,000	
Filters	330,000	
Piping and connections	4,000	
Total		$409,000
Total cost of filters with a maximum capacity of 195,000,000 gallons daily in connection with existing pumping stations		$3,391,000

In case the city is unwilling to bring itself to a reasonable use of water, and insists on wasting water as at present, the cost will be increased in proportion to the quantity of water required. The land provided for, however, at Roxborough and Queen Lane is sufficient for the construction of filters with twice the areas of those estimated for, and this item would not, therefore, increase with additional filters on those sites.

The cost of the operation of the filters may be approximately estimated upon a very liberal basis at $3.50 per 1,000,000 gallons of water filtered, or, for the quantity of water estimated for, $166,075 annually. This capitalization at 5 per cent. amounts to $3,321,500.

When additional quantities of water are required the capacity of filters at the Belmont, Roxborough and Queen Lane stations can be increased in connection with those now estimated for, the areas of land being ample for the requirements for a long period of years. The capacity of the filters on the site of the proposed Cambria reservoir, filtering water from the Spring Garden pumping station, can also be increased if desired, although the area of land available is apparently limited, and might not be sufficient for the ultimate requirements. It will, however, be better in many ways to get additional water for the district from the Delaware, instead of from the Schuylkill. Additional filters can be placed on the Delaware at any point selected as most suitable for this purpose.

As mentioned earlier in this report, investigations have not been made to determine the most advantageous point for taking the Delaware water. In case the water should be taken at a point immediately below Torresdale, works for an additional supply of 100,000,000 gallons daily would cost about $3,000,000, of which $1,100,000 would be required for filters, as much more for force mains from the filters to Market Street, connecting at various points with the pipes leading the water to all parts of the city, and $800,000 would be required for pumps, land and various accessories.

The total cost of works for securing water in this way amounts to about $30,000 for every 1,000,000 gallons daily

capacity secured, and the works would be of such a nature that any considerable part of them could be installed at nearly the same proportionate cost, and the capacity could be increased as required at the same rate. I do not consider that such a large additional quantity of water will be required in the near future, but the estimate is included that you may know the expense which will be involved in case the city insist upon having so large a quantity of water as 300,000,000 gallons or more per day.

CONCLUSIONS.

The city of Philadelphia is now using water in a most wasteful and extravagant manner, and immediate measures should be taken to check such waste, and to reduce the consumption to a reasonable amount.

It is possible to construct sand filters similar to those in use at London, Hamburg and many other European cities, in connection with the existing pumping stations, of sufficient capacity to furnish water for all reasonable requirements, for the present population, and for that which may be expected in the near future.

When larger quantities of water are required, it will be possible to secure them from the Delaware River by means of filtration, and to use the water so obtained in connection with that from the present pumping stations. The quantity of water which can be secured in this way is practically unlimited, at least 1,000,000,000 gallons being available.

The cost of installing filters with all necessary accessories to filter an average of 100 gallons of water per day for every inhabitant in the city, and with a maximum capacity of 150 gallons per inhabitant per day, amounting to 195,000,000 gallons daily in all, may be approximately estimated at $3,400,000.

85 Water Street, Boston, Mass.,
September 1, 1896.

ELECTRICAL SECTION.

Stated Meeting, Tuesday, September 22, 1896.

MR. CLAYTON W. PIKE, President, in the chair.

ON THE JACQUES CARBON BATTERY, AND ON A THERMO-TROPIC BATTERY.

BY C. J. REED.

[At the meeting of the Electrical Section of the Franklin Institute, held September 16th, Mr. C. J. Reed repeated, by request, some experiments on various modifications of the Jacques battery, and also exhibited several forms of his "thermo-tropic" battery.

He described the thermo-tropic battery or junction as a variety of thermo-electric junction, consisting of two pieces of metal separated by an intervening film of metallic salt, oxide or hydrate.

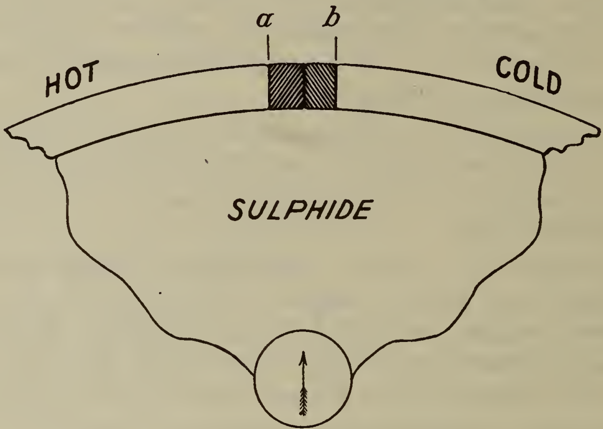
Thermo-tropic couples consisting of two pieces of copper separated by a film of copper oxide were shown. A piece of sheet copper connected to the negative terminal of a Weston voltmeter, and held in a horizontal plane, was heated to a dull red heat by a Bunsen flame placed beneath. A piece of No. 7 copper wire connected to the positive terminal of the voltmeter was then brought in contact with the upper surface of the hot sheet of copper. A deflection indicating nearly 0·4 volt was obtained.]

DISCUSSION.

ELIHU THOMSON.—My observations and experiments with cells such as that invented by Dr. Jacques have tended to show that the air introduced has for its function the formation of a film of oxide on the iron-containing cell wall, and that during the action of the cell this oxide film is continually reduced to metal, possibly by nascent sodium from the sodium hydrate.

It is well known that carbon in the presence of hot melted sodium hydrate tends to reduce it, and that at a sufficiently elevated temperature the reduction actually takes place and sodium is liberated. At lower temperatures there may be formed a polarized molecular chain, which, by oxidation of carbon, sets free the sodium ions at the other pole so as to reduce the iron oxide continually forming from the oxygen of the air introduced.

Turning now to the experiments of Mr. C. J. Reed, and especially that with the copper wires with a layer of copper oxide between, it appears to me that the effects obtained



are essentially thermo-electric, the film of oxide representing an exceedingly short element, the junction of which with the hot copper on one side is so much higher in temperature than the junction of the film on the other side as to give a considerable potential. There may be facts which would negative or modify this view of the action, but as yet I am not aware of any. Suppose the oxide to be replaced by sulphide and thickened somewhat. We would then have the arrangement in the above figure, where *a* would be a hot copper and copper sulphide junction, and *b*, a cooler sulphide and copper junction, with the result of the production of E.M.F.

Many years ago, in Philadelphia, while experimenting with thermo-junctions, I noticed effects similar to those brought out by Mr. Reed, *i. e.*, on touching a cold piece of zinc with a copper wire that had been scaled by heating in the air, and which was still hot, a quite strong deflection was obtained with a galvanometer in the circuit connecting the two metals, and that this deflection exceeded by several times that obtained when the metals were used as a simple junction heated in the usual way.

It appears to me that what Mr. Reed has done is to very greatly reduce the length of the badly-conducting element of the couple, namely the oxide or other metallic compound. It is too early to predict the practical value of the arrangement, but it is sincerely to be hoped that the thermo-electric principle of generation of current may possibly in this way reach a practical development not otherwise possible.

I shall certainly be interested to learn of the further work of Mr. Reed in this very fascinating study. I regret that distance prevents my being present at the meeting of the Electrical Section.

Mr. Reed.—The fact stated by Prof. Thomson, that a film of ferric oxide on the cell wall of the Jacques battery undergoes continual reduction to metallic iron, is very instructive. It is quite certain that, whatever the nature or origin of the current may be, whether it be galvanic or thermo-electric, it must, by electrolytic action, cause at the cell wall a reduction of some constituent of the electrolyte. If the electrolyte consists of pure sodium hydrate, the only possible reduction products are hydrogen and sodium, either of which, at the temperature employed, reduces all known oxides of iron to the metallic state. I think, however, there is a more probable explanation of the reduction of the iron.

It is well known that alkaline hydrates, at the temperature employed in the Jacques battery, oxidize iron with formation of alkaline ferrates. The electrolyte, therefore, instead of being a pure alkaline hydrate, is undoubtedly a mixture of alkaline hydrate and alkaline ferrate, from which the iron would be reduced directly by the current more easily than either hydrogen or the alkali metal. It seems

to me more probable, therefore, that there is original reduction of the iron rather than of sodium, since sodium cannot be reduced under any conditions except such as would first and more easily reduce iron. This would be particularly true if the reduction were not electrolytic, but by contact with heated carbon, as Prof. Thomson assumes.

The facts stated by Prof. Thomson suggest that a more suitable electrolyte than alkaline hydrates and ferrates might be found in such salts as the alkaline arsenates, arsenites, bismuthates, plumbites, zincates, chromates and manganates, formed by fusing the oxides of arsenic, bismuth, lead, zinc, chromium and manganese with the alkaline hydrates. All these salts, except the plumbites and zincates, are capable of reduction by forming a lower oxide and without reducing a metal to the free state.

I agree with Prof. Thomson that the thermo-tropic junction is only a species of thermo-electric junction in which one metal is replaced by an electrolyte. At one time I thought the development of E.M.F. might be due to the flow of heat across the film of the electrolyte from one piece of metal to the other; but it involves less theory to suppose that the fused and solid electrolytes have an enormous thermo-electric power, and that the cold wire acts merely as a conductor to complete the circuit.

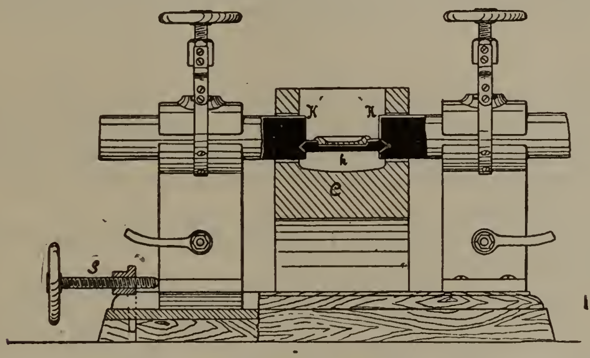
Without wishing to discourage the hope that a practical solution of the coal problem may be reached by thermo-electric batteries containing electrolytes of high thermo-electric power, I believe that the most serious defect of all galvanic batteries will also be found lurking in all thermo-electric batteries containing electrolytes. I refer to the fact that in all such batteries the evolution of electrical energy depends upon and is commensurate with the mechanical destruction of the apparatus itself, the cost of renewing which is always much greater than the entire cost of the fuel itself.

NOTES AND COMMENTS.*

AN ELECTRIC ASSAY FURNACE FOR RICHARDS' METHOD OF SEPARATING GOLD AND SILVER BY VOLATILIZATION.

In the discussion of Dr. Richards' paper on the separation of silver and gold by volatilization, it was suggested that it would be advantageous in this operation to employ electric heat, for the reason that in a properly constructed furnace of this type, the temperature could be much more readily controlled than by the use of the blowpipe flame.

Commenting on this suggestion, Dr. W. Borchers, in a recent impression of the *Zeitschrift für Elektrochemie*, describes an electric furnace devised and used by him for metallurgical work on the laboratory scale, and which he recommends as being well adapted for the special purpose above named.



Referring to the cut, *K* and *K* are two carbon electrodes about 40 millimeters in diameter, between which is placed a small carbon bar *k*, 6 to 8 millimeters thick. This bar is hollowed out to receive the test piece, and if it be desired to avoid bringing it in contact with carbon, the hollowed portion may be given a lining of magnesia, or of some other suitable refractory material.

This arrangement of parts is, as shown by the cut, enclosed within a suitable crucible *C*. To avoid the rapid burning out of the carbon bar, a few fragments of charcoal are thrown into the crucible. The manner of holding the bar *k* in position, and of introducing the current is so obvious as to need no special description. The electrode support on the left is made adjustable, so that the carbon cradle for the test piece may be firmly held in place by operating the hand-screw *S*.

According to Borchers, a current density of 5 ampères per square millimeter of section of *k* at the recessed part, will, be sufficient for the purpose of the assay. W.

* From the Secretary's monthly reports.

PRACTICAL HINTS ON WORKING ALUMINUM.

The following practical hints on manipulating aluminum for various purposes are abstracted from various communications which have appeared in the *Aluminum World:*

In *annealing aluminum* an even heat should be maintained in the muffle, and the metal, on being withdrawn, should be allowed to cool slowly. The temperature should be such that a piece of iron or steel placed in the muffle in the dark will show a red heat; for annealing thin sheet, a much lower temperature will suffice. The best test as to when the aluminum has come to the proper heat is to observe whether the metal will char the end of a pine stick, which should leave a black mark behind it as it is drawn over the plate. The metal should be at this temperature throughout, and not only on the surface.

For thin sheet and wire, it is sufficient to draw the pieces slowly over a fire and observe, by bending the metal, whether it has become soft enough.

The extreme ductility of aluminum makes it one of the readiest metals to work under the rolls. It is best to roll the larger ingots hot, that is, at a low annealing heat.

Aluminum becomes hard and loses its ductility under rolling, and therefore requires annealing during the process. When the plate is soft from recent annealing, it will stand a very considerable reduction in thickness on each pass through the rolls; but as it becomes hard, the draught must be light to avoid cracking.

Aluminum can be rolled so as to be quite stiff. The hardest rolled aluminum has about the temper of hard brass.

Aluminum, either in the pure state or alloyed with a few per cent. of hardening ingredients, can be rolled into any sections in which steel is rolled. In estimating the relative weights of the aluminum to the steel sections, the fact should be borne in mind that the sections in steel weigh 490 pounds to the cubic foot, and that the corresponding aluminum sections will weigh 168 pounds to the cubic foot, the ratio being 2·847 : 1.

Cast aluminum can be very much improved in rigidity and tensile strength if afterwards subjected to the drop-forging process. For special light-running machinery, drop-forgings of the nickel-aluminum casting metal produced by the Pittsburgh Reduction Company are particularly well adapted.

Plating Aluminum.—A process for cleaning the surface of aluminum, either for soldering or plating, is to dip the sheets into nitric acid diluted with three times its bulk of hot water, and which has had added to it just enough hydrofluoric acid to cause it to act on the surface of the metal, this action being denoted by the evolution of gas bubbles. The solution can be kept either in a wooden or lead-lined tank, and the amount of hydrofluoric acid added need be only small, say less than 5, or, at most, 10 per cent. of the volume of the solution. The hydrofluoric acid of commerce, sold in leaden jugs, and costing about 5 cents per pound, will answer the purpose.

The aluminum, after being cleaned in this dilute nitric and hydrofluoric acid solution, is again dipped into hot water for rinsing and dried in hot saw-

dust; it is then cleaned, so that either solder or plating solutions can be readily applied.

Aluminum which has been specially cleaned by any of the means suggested in the preceding paragraph, can be readily plated with copper in the way that such platings are usually applied.

Upon the copper plating, which can be put on in a very adhesive coating of any desired thickness, either gold, silver, nickel or other plating solutions can be applied. In some cases, aluminum can be advantageously plated with other metals directly, without first plating with copper.

Aluminum is now sold at a price per pound nearly equal to that of nickel, and not largely in excess of that of German-silver; volume for volume, it is much cheaper than German-silver, and for replacing German-silver or Britannia metal as a base in silver-plated vessels, its power of retaining heat, and its lightness, together with its much cheaper price, give it such advantages as will cause its extensive use.

After being plated with silver or copper, the article may be treated by the sulphide process for "oxidizing," giving the same results as "oxidized silver."

Another method consists in first cleaning the aluminum with an alkaline carbonate, after which it is thoroughly washed in water. This is followed by an immersion in a 5 per cent. solution of hydrochloric acid and another washing in pure water. A preliminary deposit of copper is then placed on the article by immersing it in a weak, but slightly acid, solution of sulphate of copper. It is then thoroughly washed and placed in the electrolytic bath.

How to Work Aluminum.—A brass scratch-brush, run at a high speed, is used on sand castings. This work can be somewhat lessened by first taking a leather wheel and a very fine Connecticut sand, and revolving this wheel at a high rate of speed on a polishing lathe, feeding the sand at the same time between the wheel and the casting, so that the skin and irregularities in the surface are removed, and then putting the casting on a buffing-wheel, or scratch-brushing it; in this way a variety of different effects can be produced. A fine brass scratch-brush gives a most beautiful finish to sheet metal or to articles manufactured from the sheet. By this means a frosted appearance is given to the metal, which effect, in many cases, is equal to that given by a high polish.

An effect similar to the scratch-brush finish can be given by sand-blasting. The effect of first sand-blasting and then scratch-brushing sheets gives a finish with very much less labor than with the scratch-brush alone.

Another very excellent frosted effect is secured by first sand-blasting and then treating as hereinafter described.

A very pretty mottled effect is secured on aluminum goods by first polishing them, and then holding them against a soft pine wheel run at a high rate of speed on a lathe, and, by careful manipulation, quite regular forms can be obtained.

This can be varied by first scratch-brushing or sand-blasting, and then holding it against a wheel as above described.

The same effect to a certain extent is given to aluminum by sand-blasting,

and aluminum which has been sand-blasted receives a grain which will allow of printing on the surface of the sheet with the best results, and aluminum sheets thus prepared are coming very largely into use for photo-lithographic purposes.

The surface in such cases is first sand-blasted in order that it shall take and retain the ink, and produce very clear and sharp outlines when printed from.

The faces for cyclometer dials, watch dials and similar articles, are generally sand-blasted before they are printed upon, which gives a very fine white background.

For dipping and frosting, remove the grease and dirt from the plates by dipping in benzine. To whiten the metal, giving a handsome frosted surface, the sheet should be first dipped in a strong solution of caustic soda or potash; then in a solution of undiluted nitric acid; then washed thoroughly in water and dried as usual in hot sawdust.

For burnishing use a bloodstone or steel burnisher. For hand burnishing, use either a mixture of melted vaseline and kerosene oil, or a solution composed of two tablespoonfuls of ground borax dissolved in about a quart of hot water, with a few drops of ammonia added.

Castings are polished by the use of a solid felt wheel, or a muslin wheel, as the nature of the work requires. In either case the wheel should be coated with emery of about No. 100 fineness, the emery being applied in the usual way with glue.

For "cutting down" sheets, use a muslin wheel with tripoli. For putting on a fine finish, or "coloring up" either castings or sheets, use a canton flannel buff, with snow-flake oil, or some other good coloring rouge.

If a particularly fine surface is desired in either castings or sheets, it is well to use, after polishing the castings, or after "cutting down," in the case of sheets, a sheepskin buff with pumice stone and oil.

The best lubricant to use on aluminum when being turned in the lathe is either petroleum or water, and in the press, when the metal is being drawn or stamped, vaseline.

THE NEED FOR AN IMPROVED TROLLEY.

The *Electrical World* says, editorially, that it is generally recognized that the trolley is a weak point in an electric railway equipment, yet no determined effort has been made to meet this deficiency. This weakness consists in the absence of that most important requisite in a device of this character—reliability. The standard trolley, now almost universally used, is prone to jump the trolley wire at any moment, and render the car helpless for the time being. This happens so often that its occurrence has of late almost ceased to excite any apprehension or comment. It is frequently the case that needed and imperative reforms are neglected through sheer indifference, and not until an unavoidable accident happens is any real effort put forth to remove the cause. Any one at all observant cannot fail to discern the possible danger brought about by the trolley jumping the wire when the car is

upon a grade, or of a car getting stalled from like cause while crossing a railway track. Two serious accidents resulting from these very circumstances have occurred in the immediate vicinity of New York within a short time, proving that these fears are well founded. A few weeks ago a car on a Brooklyn road ran backward down a hill by reason of the trolley jumping the wire, and only recently a car slipped its trolley connection while crossing a railway track, and in this helpless condition was struck by a train. Apart from the question of blame for these accidents, they demonstrate most emphatically the danger to which many lives are daily exposed in cities and suburbs through the uncertainty of the trolley staying where it belongs. If an improvement in electric railway equipments was ever needed it is certainly presented here, and it is assuring that one concern has produced a trolley device that is designed, among other things, to avoid just such accidents. The solution is not a question involving great engineering skill, but simply a change from existing practice.

RULES OF THE ROAD AT SEA.

At its last session Congress finally passed, and the President thereupon approved, the bill making amendments to the proposed new rules of the road at sea. It was hoped that the new rules could be proclaimed this summer, but this is now found to be impossible.

It is the intention of the State Department to communicate with all foreign governments, asking that they agree upon some date for the rules to go into effect. It is expected that about March 1, 1897, will be the date selected. When it is agreed upon the President will issue a proclamation. The law, as it goes on the statute books, is as follows:

Article 15. All signals prescribed by this article for vessels under way shall be given—

"(1) By 'steam vessels' on the whistle or siren.

"(2) By 'sailing vessels' and 'vessels towed,' on the fog-horn.

"The words 'prolonged blast,' used in this article, shall mean a blast of from four to six seconds' duration.

"A steam vessel shall be provided with an efficient whistle or siren, sounded by steam or by some substitute for steam, so placed that the sound may not be intercepted by any obstruction, and with an efficient fog-horn, to be sounded by mechanical means, and also with an efficient bell. (In all cases where the rules require a bell to be used, a drum may be substituted on board Turkish vessels, or a gong where such articles are used on board small sea-going vessels.) A sailing vessel of 20 tons gross tonnage, or upward, shall be provided with a similar fog-horn and bell.

"In fog, mist, falling snow or heavy rainstorms, whether by day or by night, the signals described in this article shall be used as follows, namely:

"(A) A steam vessel having way upon her shall sound, at intervals of not more than two minutes, a prolonged blast.

"(B) A steam vessel under way, but stopped, and having no way upon

her, shall sound, at intervals of not more than two minutes, two prolonged blasts, with an interval of about one second between.

"(C) A sailing vessel under way shall sound, at intervals of not more than one minute, when on the starboard tack, one blast; when on the port tack, two blasts in succession, and when with the wind abaft the beam, three blasts in succession.

"(D) A vessel when at anchor shall, at intervals of not more than one minute, ring the bell rapidly for about five seconds.

"(E) A vessel when towed, a vessel employed in laying or in picking up a telegraph cable, and a vessel under way which is unable to get out of the way of an approaching vessel through being not under command, or unable to manœuver as required by the rules, shall, instead of the signals prescribed in subdivisions (A) and (C) of this article, at intervals of not more than two minutes, sound three blasts in succession, namely: One prolonged blast, followed by two short blasts. A vessel towed may give this signal, and she shall not give any other.

"Sailing vessels, and boats of less than 20 tons gross tonnage, shall not be obliged to give the above-mentioned signals; but if they do not, they shall make some other efficient sound signals at intervals of not more than one minute.

"Section 2. That said act of August 19, 1890, as amended, shall take effect at a subsequent time, to be fixed by the President by proclamation issued for that purpose."—*Scientific American.*

ELECTRICITY DIRECT FROM CARBON.

The following paper was presented by Dr. Alfred Coehn to the *Electrotechnischer Verein*, of Berlin, and is reproduced from an English translation of the *Engineering and Mining Journal*:

The problem of the direct production of electricity from carbon would find its simplest solution if we could succeed in dissolving carbon in a fluid, just as we do metals. This question is formulated thus by the theory of electrolysis: Can carbon form ions?

In attempting to find an answer to this question, I started from an observation made by Bartoli and Papasogli, that when dilute sulphuric acid was electrolysed between carbon electrodes, the carbon anode takes part in the electrolytic processes, in such a way that, besides oxygen, both carbonic oxide and carbonic acid make their appearance at the anode. I began my experiments by varying the important factors, viz.: concentration, temperature and current density, in order to discover whether it was possible to obtain the products of combustion without admixture of oxygen on the anode. I have not succeeded in obtaining carbonic acid or carbonic oxide alone, but a mixture of the two, containing only 1 per cent. of oxygen. In this mixture about 70 per cent. was carbonic acid and 30 per cent. carbonic oxide.

In these experiments it was observed that at low temperatures a disin-

tegration of the carbon anode took place, small particles of carbon being seen suspended in the acid. At higher temperatures, on the contrary, no such disintegration of the carbon took place, but a distinct coloration of the acid was produced, at first yellow, then later dark red and red-brown. If this is a solution of the carbon brought about by the current, the carbon is presumably contained in it, in the form of ions, *i. e.*, in a form capable of being influenced by the directing power of the current. Such a solution must be capable of giving up carbon to the cathode, since carbon does not decompose water. (A series of platinum plates, coated with carbon, was shown, and a dish, such as is used by Classen for quantitative electrolytic analysis, was shown coated inside with a dense layer of carbon.) The solution and precipitation could readily be obtained with different kinds of coal as anode. Ordinary coal, ground smooth, and arc lamp carbons, were found specially suitable; the experiment also succeeded with coke.

That the precipitate was really carbon, and not metal derived from impurities in the coal, was shown by treatment with acids. It was not attacked by hydrochloric acid; in hot nitric acid traces were dissolved—as in the colorimetric test for carbon in steel. In the flame, even the densest precipitates completely disappeared immediately. Finally, a direct proof was obtained by oxidizing the precipitated carbon by chromic acid, and absorbing the resulting carbonic acid in alkali. A number of analyses were made, and these always showed, in addition to carbon, a little hydrogen. The residue—reckoned as oxygen—was sufficient to convert the hydrogen found into water. Either, therefore, in addition to the carbon, a solid conducting carbohydrate was separated, or some kind of crystalline water which adhered strongly to the carbon was produced. The presence of water in the precipitate is indicated by its behavior with concentrated sulphuric acid. If the acid is dropped on the precipitate it is immediately loosened and blackened, reminding one of the behavior of sulphuric acid with a carbohydrate.

It was now of interest to attempt to construct an element whose soluble electrode consisted of carbon. The only question now was to place a more electro-negative element opposite the carbon. The peroxides stand nearer even than carbon to the negative end of the potential series. Lead peroxide was used in the practical form of a charged accumulator plate. If this be placed opposite a carbon in sulphuric acid of the proper concentration, temperature, etc., an element is formed of which carbon is the soluble electrode. The element supplies a strong and constant current. Through an external resistance of 100 ohms it shows an E.M.F. of 1·93 volts.

There arises here the question whether any share in the production of the current is due to the reaction on the carbon, and if so, what share? Platinum also, when placed opposite a peroxide plate under the same conditions, shows a current in the same direction as the carbon. But it never comes to a visible development of oxygen; as soon as the platinum is charged with oxygen the current becomes exceedingly small. If the carbon were an insoluble electrode it would behave in the same way; but this

is not the case. The current lasts till the accumulator plate is discharged. A second charged peroxide plate may then be substituted, and the current is again produced as strong as before.

The results of my investigation may be summarized as follows:

(1) It is possible by electrolysis to produce a solution of carbon.

(2) From such a solution carbon may be separated as a kathion.

(3) An element may be formed of which carbon is the soluble electrode.

NEW USE FOR OLD HORSE CARS.

We learn from the *Electrical World* that a novel but very sensible use is made of old horse cars in Connecticut. When the trolley system was introduced in the various cities in that State, the problem as to what should be done with the old horse cars remained unsolved, until some enterprising genius suggested using them for summer cottages, hunters' camps, lodges, etc. The public readily fell in with the idea, with the result that all of 600 old cars that went into disuse are now being utilized for these novel purposes. It is stated that all along the Long Island coast, from Watch Hill to Larchmont, these cars may be seen perched up on top of some breezy bluff on the sandy shore, or in some quiet, shaded nook, affording temporary habitation for families, fishermen, hunters, etc. The demand for old horse cars has greatly increased in consequence of this new use. One woman recently asked the station agent at New London for his lowest prices for passenger cars, also a list of the various styles. A Norwich party has arranged four cars in the form of a hollow square, and erected a canvas awning in the square. One of the cars is used as the kitchen and the others as sleeping-rooms, dining-room, parlor, etc. One gentleman has five cars on Block Island, which he has placed end to end, like a train. The supply of old cars in this one State has thus suddenly become exhausted.

PROCESSES FOR THE NICKEL-PLATING OF WOOD.

The nickel-plating of wood for various decorative uses, such as canes, umbrella handles, etc., is extensively practiced both in Europe and this country. The *Electrical World* gives the following formula for the purpose:

The articles which are to be plated with nickel must first be coated with metal. In the process which is most commonly employed three solutions are made use of, namely: (*a*) 1½ grams of caoutchouc slicings are dissolved in 10 grams of carbon bisulphide, and 4 grams of melted wax are poured into the solution; a mixture consisting of 5 grams phosphorus in 60 grams of carbon bisulphide, with 5 grams of turpentine and 4 grams of powdered asphalt, is then added and the whole shaken. (*b*) 2 grams of silver nitrate are dissolved in 600 grams of water. (*c*) 10 grams of chloride of gold are dissolved in 600 grams of water. The conducting wires are attached to the article, which, after being immersed in the first solution, is allowed to dry. The second solution is poured over it, and it is kept suspended until the sur-

face has a dark luster, when it is rinsed with water and treated in a similar manner with the third solution. The surface has now a yellowish sheen, and the wood is sufficiently prepared for electrolytic deposition. Langbein's dry process consists in quickly pouring over the article a collodion solution of potassium iodide, diluted with an equal volume of ether-alcohol; when the layer is just about to set, the wood is laid in a weak solution of silver nitrate, light being excluded. As soon as a yellow color appears, the wood is rinsed, exposed to sunlight and covered with copper; it is then ready to be nickel-plated. The wood may also be treated with immersion in an ethereal solution of paraffin or wax, and when the ether has evaporated, fine graphite is powdered over them, or the wax is covered with bronze powder, and all unevenness of surface removed. When the articles are to be electrolytically coated with copper they are placed in a bath the composition of which varies with the current employed; generally, it consists of 30 liters of 18 per cent. copper sulphate solution, and 1½ liters of 66 per cent. sulphuric acid. When a sufficient amount of copper is deposited the articles are ground, polished and nickel-plated in a bath composed of 500 grams of ammonium-nickelous sulphate, 50 grams of ammonium sulphate, and 10 liters of distilled water. If the blue litmus paper be quickly reddened by this solution, the acidity is reduced to such a point by addition of ammonium chloride that the reddening is only slowly developed.

ROLLER SHIP LAUNCHED.

In the presence of numerous foreign engineers and a large crowd of onlookers, the so-called "roller steamer," the invention of M. Bazin, a well-known marine engineer, was launched August 19th, at the Cail dock-yards, at St. Denis, France. The vessel will traverse the Seine, cross the English Channel, and go to London.

The boat is a large, rectangular iron box, about 120 feet in length, 40 feet wide, and 5 feet high. It is mounted on six lenticular discs or rollers, 30 feet in diameter and sunk in the water 10 feet, while the lower floor of the box is at an equal distance from the level of the water. In the sides of the box is the machinery, which is of 750 horse-power. This sets in motion a screw and the rollers. In the upper part of the vessel, between the discs, which pierce the box and extend beyond it about 7 feet, are comfortable cabins. This strange-looking vessel has a displacement of 280 tons.

M. Bazin's first experiments were made with a small model, the rollers of which were moved by clockwork, the propeller being replaced by a weight, which was attached by a string passing over a pulley to the front of the boat. When the rollers were not working the miniature boat took twenty-two seconds to cross from one side of the large vessel in which it was placed to the other side. When they were working it took only eleven seconds. As the power necessary to keep the rollers at work is only one-quarter of the power that is required to keep the screw going, the mathematical result is that the speed of the vessel is doubled by an extra expenditure of power, which amounts to only one-quarter. But a vast increase of speed is not the only advantage claimed

for these rolling steamers. It is pointed out that when they shall be used the length of voyages will be diminished, the consumption of coal will be lessened, and, as a natural result, passengers and freight will be transported at far less expense than heretofore. Moreover, experts assert that the stability of the rolling boats will be far greater than that of the steam vessels at present in use. It is also asserted that the catastrophes at sea would practically cease by the use of rollers. In case of a collision or other accident, though some of the rollers might be damaged, some would almost certainly escape damage, and two would suffice to keep the vessel afloat and take her into port.

M. Bazin expects the boat to make from 45 to 50 kilometers an hour while crossing the channel. The theory of the inventor is that boats should roll over the water instead of cutting through it.

He has designed a large steamer on the same principle, which he estimates will make the voyage from Havre to New York in four days, but of course this speed is largely problematical.—*Scientific American.*

DAMASCUS GUN-BARRELS.

The making of barrels for sporting guns in the valley of the Vesdre, in the province of Liège, Belgium, is an interesting mechanical operation. These barrels are called "damascus," because the damascene appearance of the metal resembles that of the celebrated Damascus sword-blades, famous for their fine quality. The damascus gun-barrels herein described are made entirely by hand. The United States Consul at Liège has described this manufacture in one of his reports, from which we make the following abstract: The steel is imported from Westphalia; the iron is manufactured at Couvin. The factories receive their motive power from the River Vesdre. Some years ago, forges and workshops were entirely engaged in making iron barrels, and there were but few barrel-makers who produced tubes or barrels known as twist barrels, called by the French *canon tordu*, or *tors*, from *tordre*, to twist or contort. The ingot for the production of the curled damascus, which is the favorite design for fine guns, is composed of about thirty sheets of iron and steel, each having the thickness of 4 millimeters and a breadth of 120 millimeters, which form a square mass about 50 centimeters long, and are enveloped in a box of common thin sheet-iron or by small wires at each end. The package thus prepared is put into a furnace and welded together at the lowest possible temperature. Too great a heat destroys the metal and yields a burned damascus, showing a small, if any, design. Each barrel receives 150 welding heats while being forged. If one of these welding heats is unsuccessful, the barrel may be a failure, either by the alteration of the damascene appearance or by a trace of the smallest imperfection in welding. Swedish iron is not used in forming curled damascus; only refined iron of Belgium, which gives a greater contrasting hue to the steel, and can be welded at a lower heat. After the ingot is welded it is rolled into small square rods of 7 to 9 millimeters, according to the design of the damascus desired.

The rods are then drawn into ribbons by the smiths. The manipulation of these ribbons at high temperature is such that in a length of 1 meter, 200 twists are shown. Coke iron will not answer for this fine work, for which charcoal iron is used exclusively, though an inferior quality of damascus can be made from coke iron. The twisting increases in pitch toward the thinner part of the barrel, which is first formed by winding the ribbons on a mandrel, and welding the coils together at the edges. The barrels are then bored out, straightened, ground to the proper thickness and polished. The joining of the barrels for double-barreled guns is a process requiring great care, as the value of the gun largely depends upon the accuracy with which this part of the process is executed. Each barrel is proved by a shooting test at the manufactory before it is placed on sale. It is said that the annual production of these barrels is 300,000, and that they are exported chiefly to England and the United States.

BOOK NOTICES.

The Dynamo. How made and how used. By S. R. Bottone. Ninth edition, with additional matter and illustrations. New York: Macmillan & Co., 66 Fifth Avenue. (John Wanamaker, Philadelphia.) Price, 90 cents.

The favor with which this guide for the amateur in the construction and use of the dynamo has been received is tolerably good evidence of its usefulness. Books of this class fill a gap for which the scientific treatises afford no substitute, and, with fair accuracy of statement in what relates to essentials, have an educational value for a numerous class which it would be difficult to overestimate. Mr. Bottone's book is one of the best of its kind. For a future edition we would suggest to the publishers the desirability of better illustrations. In these days of cheap engraving, the reprinting of old and badly worn cuts and the use of crude sketches for originals is unwise, to say the least. W.

PUBLICATIONS RECEIVED.

[In sending books for notice in the *Journal*, publishers are requested, for the information of the reader, as well as for their own advantage, to give the price. This announcement by title will be followed, in most cases, by a review, which will appear at the earliest opportunity.]

Expanded Metal and its uses in fire-proof construction. Merritt & Co., Inc., engineers and contractors, Philadelphia.

Encyclopédie scientifique des Aide-Mémoire, Paris: Gauthier-Villars et fils et Masson & Cie. 1896. Price, per volume, 2.50 to 3 francs.

The undermentioned additions to this series have appeared since our last notice:

Barillot, Ernest, Directeur technique d'usines de distillation de bois,

Membre de la Société chimique de Paris, Expert-Chimiste près les Tribunaux. *La distillation des bois.*

Hennebert, Lieutenant-Colonel du Génie, ancien Professeur à l'École militaire de Saint-Cyr, aux Écoles des Mines et des Ponts et Chaussées et à lÉcole supérieure de guerre. *Communications militaires.*

Ariès, E., Chef de bataillon du Génie. *Chaleur et Énergie.*

Hennebert, Lieutenant-Colonel du Génie, ancien Professeur à l'École militaire de Saint-Cyr, aux Écoles des Mines et des Ponts et Chaussées et à l'École supérieure de guerre. *Travaux de campagne.*

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, October 21, 1896.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 21, 1896.

JOS. M. WILSON, President, in the chair.

Present, 104 members and visitors.

Addition to membership since last report, 1.

The Secretary reported the resignations of Messrs. C. O. Billberg, John E. Codman, Dr. C. B. Dudley and Fred. E. Ives, from the Committee on Science and the Arts.

An election resulted in the choice of Mr. Thomas Spencer for the unexpired term of Mr. Billberg, Mr. John Birkinbine for the unexpired term of Mr. Codman, Mr. Wm. C. Henderson for the unexpired term of Dr. Dudley, and Mr. Wm. R. Webster for the unexpired term of Mr. Ives.

Mr. Walter Atlee, civil engineer, of Philadelphia, read a paper "On the Improvement of the Channel of the Delaware River," setting forth what had already been accomplished, the plans at present being carried out and in contemplation for the future, for obtaining and maintaining an unobstructed deep-water channel in the river, from Philadelphia to the sea, capable of accommodating vessels of the largest draught. The speaker illustrated his paper with the aid of charts and lantern slides, exhibiting the depth and other physical characteristics of the river channel from Trenton to the sea.

The subject evoked a spirited discussion, which was participated in by Lieut.-Commander J. R. Selfridge, U. S. N., late in charge of the Branch Hydrographic Office, Philadelphia; Mr. L. Y. Schermerhorn, Mr. J. C. Trautwine, Jr., Prof. Lewis M. Haupt, Mr. Edwin F. Smith, Mr. Frank Rosengarten and others.

(Paper and discussion will be referred to the Committee on Publications.)

Adjourned. WM. H. WAHL, *Secretary.*

JOURNAL

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OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXLII. DECEMBER, 1896. NO. 6

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, October 21, 1896.

MR. JOS. M. WILSON, President, in the chair.

THE IMPROVEMENT OF THE CHANNEL OF THE DELAWARE RIVER.

BY WALTER ATLEE, C.E., Member of the Institute.

The Delaware River is the largest tidal river in the world upon which a comprehensive improvement of the natural channel has ever been attempted. The magnitude of the problem is so much greater and the conditions so different that the precedents established in other tidal rivers do not apply, except approximately, upon the Delaware.

Notwithstanding the magnitude and the difficulty of the problem, the extent of the improvement of the natural channel of the river, which has been accomplished during the last ten years, is greater than that obtained during an

equal interval of time upon any river at all approximating the Delaware. While there yet remains much to be done in the improvement of the main ship channel between Philadelphia and the sea, that which has been accomplished is an admirable tribute to the means which have been employed and the skill which has directed these means. To a continuance of this skill and the methods of the past must we look for the final successful improvement of the Delaware River.

The improvement of the Delaware River, as a whole, has been divided into three sections, as follows:

(1) From Trenton to Fisher's Point, a distance of 29 miles.

(2) From Fisher's Point to Kaighn's Point, a distance of 6 miles.

(3) From Kaighn's Point to deep water in the bay.

Upon this first section, viz.: between Trenton and Fisher's Point (see plan), there has been no comprehensive project or estimate submitted beyond that required to obtain a channel 12 feet deep over Kinkora Bar. Kinkora Bar now carries a depth of about 8 feet at mean low water; the area between the mouth of the canal at Bordentown and White Hill carries a depth of about 6 feet, and the channel between Bordentown and Trenton has about the same depth at mean low water. The physical character of this division of the Delaware is such as to render its rectification difficult and very expensive. Its commerce has never been such as to press upon the attention of the Government the need for its extended improvement.

The second section of the river, that between Fisher's and Kaighn's Points, covers the improvement of the Philadelphia harbor.

The original project for this improvement was recommended by a Board of United States Engineers on March 30, 1888, and adopted by Congress in the River and Harbor Act of September 19, 1890. It proposes the formation, by dredging, of a channel about 2,000 feet wide, extending along the Philadelphia shore from opposite Kaighn's Point to opposite Fisher's Point, at a distance far enough removed

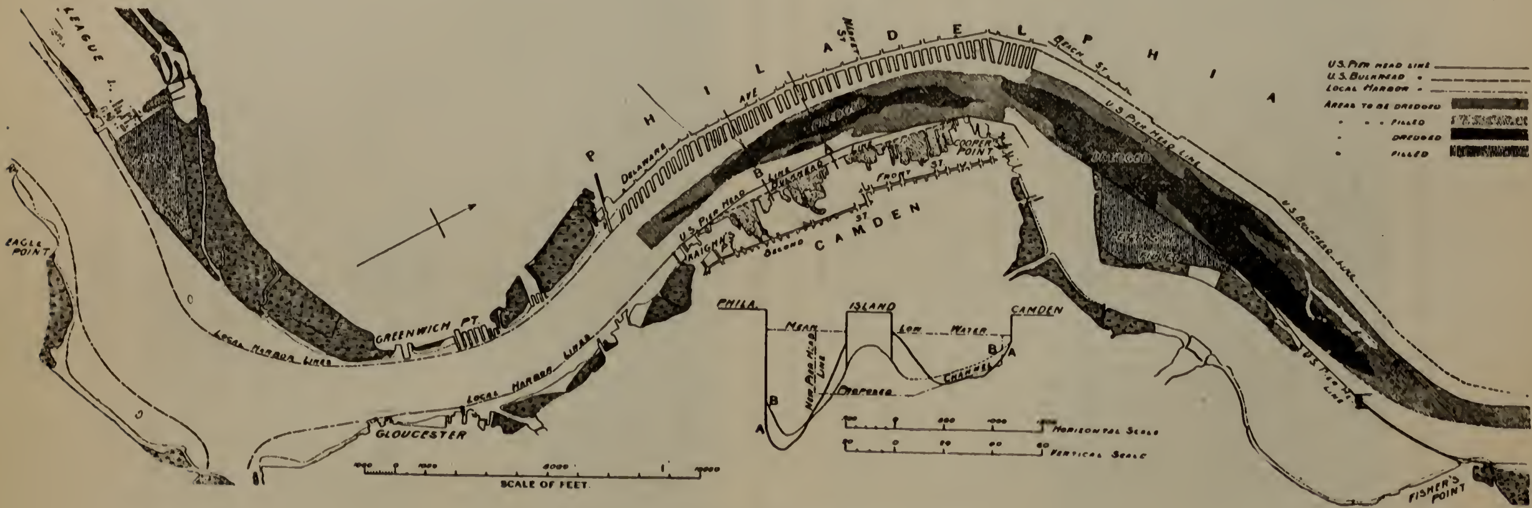

FIG. 1.—Sketch of Philadelphia Harbor.

from the present wharf line, to permit the extension of the wharves and the widening of Delaware Avenue at their shore ends. It involves the removal of Smith and Windmill Islands, adjacent shoals and a part of Petty Island, so as to give a depth of 26 feet at mean low water in a channel about 1,000 feet wide along the revised Philadelphia wharf line, this channel decreasing to a depth of about 12 feet along the Petty Island front; the building-out of the Philadelphia and Camden shores, so as to preserve a cross-section of about 55,000 square feet at mean low tide.

This project was modified by Congress in Acts of March 3, 1891, and July 13, 1892, so as to provide for the deposit and spreading of dredged material on League Island and elsewhere. The quantity of material to be removed was about 18,000,000 cubic yards, place measurements; the cost of the dredging required to carry out this project was estimated at $3,500,000. This scheme further provides for the simultaneous regulation of the Port Wardens' lines of both the Pennsylvania and New Jersey shores of the river, so as to maintain the assigned cross-section of the new channel and the establishment of these lines by actual construction during the progress of the work. The reconstruction of the water-fronts to conform to the new lines will be executed at the expense of the cities of Philadelphia and Camden and the other riparian owners. The cost of this reconstruction for that portion of the Philadelphia front from opposite Kaighn's Point to opposite the lower end of Petty Island, exclusive of the cost of property for widening Delaware Avenue, has been estimated at $8,000,000.

In the River and Harbor Act of September 19, 1890, the Secretary of War was authorized by Congress to enter into a continuous contract for the completion of this improvement, under such appropriations as Congress might make from time to time. Since 1890, provision has been made for carrying on the improvement by yearly appropriations contained in the Sundry Civil Bill.

The improvement was initiated in 1890 by an appropriation of $300,000 by the general Government, of $200,000 by the State of Pennsylvania, and $218,652.86 by the city of

Delaware River, from Philadelphia side, showing islands before removal.

Delaware River, from Camden side, showing islands before removal.

[Photographs by Gutekunst.]

Philadelphia, for the purchase of the islands to be removed and the property thereon.

The total amount appropriated by the general Government up to this time for this work is $2,940,000, leaving $660,000 yet to be appropriated for its entire completion.

Previous to the removal of the two islands between Philadelphia and Camden, they caused the flood and ebb tides to pursue different paths, and so narrowed the channels, which were forced so near the shores as to prevent the construction of wharves necessary for the purpose of commerce.

In April, 1891, a contract was entered into for the execution of this work, but before the close of the following year it was annulled for failure "to prosecute the work faithfully and diligently."

Work was begun under a contract on June 1, 1893, by the American Dredging Company, of Philadelphia, and has been kept up almost continuously ever since.

This contract provides for the complete execution of the work, to be paid for as appropriations may be made from time to time by law, and for the continuance of the work as rapidly as may be required to the extent of dredging 400,000 cubic yards in any one calendar month, provided funds are available for payment therefor.

The work required the removal of all trees, structures, pile and timber wharfing and revetment from the islands. Their surface averaged about 9 feet above mean low water and about 3 feet above mean high water. The area of the islands to be removed was about 150 acres. A portion of the Windmill Island was revetted with crib work backed with stones. All timber had also to be removed from the dikes which formed the cross channel (see plan), also the removal by dredging and scouring of about 21,500,000 cubic yards of material.

In this work the American Dredging Company employed from 10 to 14 dipper and grapple dredges, manned by from 300 to 400 men, in excavating the material, which was placed in from 75 to 90 scows, each with a capacity of from 250 to 600 yards.

Three hydraulic dredges were employed to pump and spread the material from these scows, which was placed on League Island and elsewhere. From 18 to 25 steam tugs were employed in towing the scows from which the material was dumped. These tugs hauled from 4 to 14 scows at each tow, moving with the tides, their average round trip being from 20 to 50 miles.

The consumption of coal per month varied from 2,000 to 2,500 tons. There were also about 100 men employed in the repair and construction shops. The equipment represented an invested capital of $1,250,000. The material removed varied from clean sand and soft clay to hard clay and gravel.

There has been, so far, removed in all 24,848 linear feet of timber and revetment from Smith and Petty Islands and the shores and interior basin of Windmill Island; and the removal from the three islands and adjacent shoals of about 16,905,223 cubic yards by dredging, 3,252,148 cubic yards of which was deposited upon League Island, and the remaining 13,653,075 cubic yards was hauled away and dumped elsewhere.

The northern side of Petty Island has been dredged back to the New Jersey pier-head and bulk-head lines, giving, at low water, a width of 1,900 feet to the Pennsylvania channel, at this level.

All the pile and stone revetment and timber work have been removed, and the filling of spaces on League Island, as provided for in the contract, has nearly been completed. About 133 acres of land, formerly above low water, has been removed, and 282 acres, of which 135½ acres were on League Island and 146½ acres on Petty Island, formerly below, has now been raised above, high water.

At Five Mile Bar, which lies directly above the upper end of Petty Island, a dike has been constructed, extending from the New Jersey shore at Fisher's Point to within 2,000 feet of the head of Petty Island.

On June 30, 1890, this dike had reached an extension of 4,500 linear feet, which is its present length, of which the upper 3,500 feet consisted of random stone dike, founded

upon a brush mattress sill and backed with gravel and boulders derived from the excavation of the channel at Port Richmond, and the lower 1,000 linear feet of pile dike filled with stone. The tops of these constructions were carried to a height of 2 feet above mean high water. At the close of June 30, 1894, the action of the dike had formed a channel 13 to 15 feet deep and 270 feet wide across the bar. Before the formation of the dike, there was a depth less than 15 feet at mean low water, over a length of 1,200 feet, and a minimum depth of 3 feet. There is now a least depth of 23 feet over the whole length. The ledge opposite Otis Street has been entirely removed to a depth of 26 feet at mean low tide.

The increased depths which have been obtained by dredging have, in all cases, been permanent, even over the sites of Smith and Windmill Islands; where temporary deposits might have been apprehended, there is no indication of shoaling.

These deductions are derived from repeated surveys of the deepened areas, and from an experience covering active dredging operations extending over an interval of nearly four years.

The data required for the execution of the work, and the determination of its effects and changes during its progress, have been obtained from detailed hydrographic examination and surveys, based on a rigid system of triangles and range lines marked by natural objects, covering the entire distance from Fisher's to Kaighn's Points, 6½ miles. Tidal observations are registered by an automatic gauge.

The work already done upon the improvement of Philadelphia harbor has resulted in obtaining a channel at mean low water of a depth of 26 feet from Morris Street to Erie Avenue, a distance of $5\frac{45}{100}$ miles; from Morris Street to Shackamaxon Street, a distance of 14,120 feet. The channel has a minimum width of 225 feet, a maximum width of 1,000 feet, and a mean width of over 900 feet. The minimum width is only at one locality, dredged in 1894, to permit the laying of telephone and telegraph cables. Here the depth averages about 23 feet; this elevation has been left temporar-

ily during the execution of dredging above and below, in order not to disturb the cables. It will be removed as soon as the 1,000-foot channel in the immediate vicinity shall have been completed.

The next narrowest is 700 feet. The distances have all been measured from the new Philadelphia pier-head lines.

From Shackamaxon Street to pier No. 3, Richmond wharves, a distance of 7,675 feet, the maximum width of the channel is 1,000 feet, with a minimum width of 100 feet, or a mean width of 717 feet.

From pier No. 3, Richmond wharves, to Erie Avenue, it is 7,000 feet; the channel here has a maximum width of 950 feet, and a minimum width of 175 feet, or a mean width of 500 feet.

Smith and Windmill Islands have been removed to an average depth of 23 feet below mean low water.

The improvement of the third section of the Delaware River, viz.: between Philadelphia and the sea, was undertaken in accordance with a project and estimate submitted by a Board of United States Engineers on January 23, 1885. This project proposes the formation of a channel 600 feet wide and 26 feet deep at mean low water at all points where less width or depth occurs.

Before improvement, the channel had a depth less than 26 feet at mean low water, over an aggregate length of about 20 miles; and a depth less than 24 feet at mean low water over an aggregate length of about 6 miles.

The distance from Fisher's Point to deep water at the head of the bay is 61 miles.

The length of channel requiring improvement was, therefore, about one third of the total length.

There were six main locations where such improvement was necessary, as follows: Mifflin Bar, Schooner Ledge, Cherry Island Flats, Bulkhead Bar, Dan Baker Bar and Duck Creek Flats.

Except at Schooner Ledge, where the desired channel was to be obtained by dredging and the removal of rock, and at Cherry Island Flats, where dredging only was necessary, the plan proposed for obtaining the desired depth and

FIG. 2.—Sketch map of approach to Philadelphia harbor, showing the lights.

width at the locations, was the construction of dikes, by which the tidal currents would be directed and concentrated upon the shoal areas, and the channel deepened and maintained.

The estimated cost of this project in 1885 was $2,425,000, with an annual expenditure for repairs and preservation, after completion, of $87,000. Previous to 1885, about $1,500,000 had been appropriated and applied by the Government toward improving, to a depth of 20 to 24 feet, the various shoal areas in the Delaware River between Philadelphia and the sea. Since the date of the existing project in 1885, $1,617,000 has been appropriated, of which about $584,000 remain on hand.

The improvements have been executed in the order considered most immediately beneficial to navigation, so far as the physical condition of the river permitted.

Mifflin Bar is 8 miles below Philadelphia. The existing works for its improvement consist of a random stone dike, extending from the Pennsylvania shore, at Hog Island, a distance of 7,945 feet, of which length 3,257 feet have been raised above high water, the remaining distance being constructed to low water.

Before the building of the dike there was a depth of less than 26 feet at mean low tide over a length of 4,500 feet and minimum depth of 17 feet.

There is now a least depth of about 23·9 feet at mean low tide over the bar.

Schooner Ledge is about 18 miles below Philadelphia. The main ship channel was originally obstructed by a ledge of rock, which reduced the depth at mean low water to about 18 feet.

In 1879, the formation of a channel by dredging was commenced through this obstruction, and continued until 1884, when a channel was reported as formed to a depth of 24 feet for a width of 330 feet. Afterward other obstructions were discovered, and in 1889, 250 cubic yards of sand and rock was removed.

Before improvement, there were here, including the bar between the ledge and Marcus Hook, a depth less than 26 feet

at mean low tide over a length of 8,600 feet, and a minimum depth of 18 feet. There is now a depth of less than 26 feet at mean low water over a length of 7,850 feet, and the minimum depth is 21 feet. The Government has done no work at this locality since 1885; but the recent appropriation of $185,000 by the city of Philadelphia will permit the removal of the rocky ledge obstructing a part of the channel and the dredging necessary to remove all obstructions from this section of the river to a depth of 26 feet at mean low water in a channel 600 feet in width.

This work is now being done by the Philadelphia Public Works Construction Company, under contract dated November, 1895, and will probably be finished by the close of the current year.

Twenty-seven and one-half miles below Philadelphia is Cherry Island Flats. Here about $100,000 were expended in 1892–3 in deepening and widening the channel by dredging, in accordance with the adopted project. Since the deepened channel was formed, in 1893, the lower 4,000 feet has again shoaled to from 18 to 20 feet at mean low water. The entire length of the deepened channel was about 10,000 feet. The physical characteristics of the river at this locality are such as to preclude its improvement by means of dikes, and in dredging must be sought the means of obtaining and maintaining a deepened channel.

Bulkhead Bar is situated about 36 miles below Philadelphia, or 3 miles above Fort Delaware.

Formerly, this bar carried 20 to 21 feet of water at mean low tide. A dike was begun on August 25, 1890, and completed on June 30, 1892, on the east side, this dike being 4,063 feet long. This is a pile dike, filled with stones. Fifty-one thousand eight hundred and ten cubic yards of material was dredged from the channel during its construction.

There is now a depth of 28·6 feet and 600 feet in width at mean low water over the whole length (7,300 feet). The action of this dike, which has been in operation about three years, has been so extraordinarily favorable that very reasonable anticipations of its ultimate success may be in-

dulged in, and the permanent improvement of the bar accepted as almost demonstrated. Should this expectation not be entirely realized, it could undoubtedly be secured by comparatively small addition to the existing work of improvement.

Just above Bulkhead Bar there are the Pennsville Shoals; before improvement there was less than 26 feet depth at mean low water for 4,800 feet in length, with a minimum depth of 24 feet. Now, more than 26 feet, at mean low water, exists in depth over the entire length. This improvement is due to the action of the river under improved conditions.

The next locality below Bulkhead Bar requiring improvement is Dan Baker Shoal, 48 miles below Philadelphia. Here the river suddenly expands to a width of nearly 4 miles, and there exists an area in the main ship channel of several miles in length, with a depth of water of 20 to 24 feet. The Board of Engineers, of 1885, proposed for the improvement of this locality a dike about 5 miles in length, for the purpose of forcing the flood tide from the deep concavity on the west bank of the river below Reedy Island, and, conjointly with the ebb tide, secure a scouring action of the tidal currents along the main ship channel over the shoal areas forming the present bar.

This dike was to have been a low-water dike, and its average estimated cost was $324,000.

The dike was being extended under a recently executed contract, but all work thereon has been suspended under the provisions of the River and Harbor Act of 1896.

From the experience which has already been gained in the action of low-water dikes, it is highly probable that a low-water dike would not accomplish at this locality all that might be desired, and that it would ultimately require that the dike be raised to above high water; such a construction would probably increase the previous estimate to, say, $500,000. After the study which has been given to this locality, it is extremely probable that no better plan for the improvement of the Dan Baker Shoal can be suggested, unless recourse be had to dredging alone, than a dike on the

lines proposed by the Board of 1885, modified, however, by raising the dike to a height in excess of that proposed by the Board. It is also probable that the action of the dike would require to be supplemented by dredging a channel through such parts of the shoal areas as did not yield readily to the scouring action of the tidal currents. If such dredging became necessary, the estimate for the improvement of this locality would be increased to above $600,000.

At Duck Creek Flats, which is the next and last locality requiring improvement, the 26-foot curves of depth are separated by a distance of about 3 miles. For the improvement of this shoal, the Board of 1885 recommended a low-water dike along the west side of the channel, about 7 miles in length, at an estimated cost of $420,000. The dredging of a channel 600 feet wide and 23 feet deep would probably cost from .$200,000 to $300,000, and, without regulating works, the utility of such a dredged channel might be of but short duration.

At Duck Creek Flats the physical characteristics of the river cease, and those of the estuary begin. Under such conditions, the improvement of the locality requires consideration differing from that which might be applied to localities further up the river. While high-water dikes of determinate length are required for the improvement of the river section, it is probable that dikes of less height, and on different lines, would be required in the estuary section of the river. Under the light of recent experience, it is impossible to revise the recommendations of the Board of 1885 for this locality.

The improvement of the Delaware River in the vicinity of Greenwich Point has never formed a part of the specific plan for either the improvement of the river or harbor, probably for the reason that the harbor improvement, when completed, would permit a passage of the main ship channel from the west side of the river, opposite Kaighn's Point, to the east side of the river opposite Greenwich Point. It would be to the advantage of the commercial interests at Greenwich Point if the 1,000-foot deep-water channel on the Philadelphia side of the river,

from above Kaighn's Point, could be carried continuously along the same side to below Greenwich Point. To accomplish this would require the removal of about 500,000 cubic yards of material, at an estimated cost of $280,000.

The improvement of this part of the river is now under consideration by the city of Philadelphia, with funds made available by recent appropriations of Councils, and probably will be accomplished at an early date.

The total length of channel in the Delaware River improved is 52,800 feet, or 10 miles. The total length improved to full depth is 23,020 feet, or about $4\frac{1}{4}$ miles. At other localities the distance across the bars has decreased through natural causes, the aggregate decrease in length being 4,160 feet.

The full widths required by the project have been obtained at Five Mile Bar, Port Richmond, Otis Street wharf, Pennsville Shoals and Bulkhead Bar.

The benefits to commerce resulting from the improvements have been very great, especially those resulting from the removal of the two bars below Philadelphia. Previous to improvement, vessels of deep draught were compelled to utilize the high water of two tides in order to ascend the river to Philadelphia. They can now make the whole trip in a single tide.

DISCUSSION.

L. Y. SCHERMERHORN:—That which I shall say will not be a discussion of Mr. Atlee's able paper, but rather a brief statement of the reasons why we need an adequate channel to the sea, and what such a channel will accomplish for the commercial, industrial and maritime interests of the cities and States bordering the Delaware River; for, as Mr. Cramp has stated in his able letter, just read, this is a question of more than local interest, for its issues cover those belonging to States rather than communities.

Sixty years ago the ocean steamship was only a dream in the brain of Brunel, and was ridiculed by the directors of the Great Western Railway, when he, as their engineer proposed the steamship as a means for the extension of

their line across the ocean to our shores; nevertheless, their later faith in the possibility of such a dream permitted Brunel to build the steamship *Great Western*, which, in 1838, as the first ocean steamer, crossed the Atlantic and anchored in New York Harbor. This was accomplished in the face of demonstration by Dr. Lardner, the then greatest authority, that such a result was impossible. After this demonstration by Brunel, the problem was solved and the days numbered of the sailing ship as the only and best carrier.

The next great advance was the substitution, in 1845, of the screw-propeller for the side-wheel as the means for propulsion; since the latter date the wonderful advance which has been made in ocean steamships has simply been in better and larger hulls and motive-power construction.

The development of steamships to the date of less than twenty years ago, except in rare instances, had produced an ocean freight carrier with a length of less than 300 feet, with a loaded draft of less than 20 feet, and with a carrying capacity of less than 4,000 tons. At that time the leading seaports of the North Atlantic—Boston, New York, Philadelphia, Baltimore and Norfolk—all carried a sufficient depth of water over their harbor or channel bars to freely admit the standard ocean steamship. Under such conditions wharves of 200 or 300 feet in length, such as we had in Philadelphia, and the depth of 20 feet which existed over the bars in the channel of the Delaware River, was enough to allow the ocean carriers of the world to commodiously reach us and permit the port of Philadelphia to carry on a business which was fairly competitive with its rival ports. The port of Philadelphia then stood in commercial importance next to New York, and thereby ranked as the second in the United States; to-day its position is a doubtful fourth, and the causes which have largely contributed to such a condition are as follows:

Competition in business always tends to the lowering of prices on one hand, and the effort to meet the reduced profit by cheaper methods on the other hand. Experience has demonstrated that ocean freight can be more economically carried in larger hulls with greatly increased motive-power,

designed to shorten the time of ocean transit and also reduce the consumption of coal and thereby the quantity carried; accordingly, ocean steamships were designed with largely increased dimensions and motive-power, which greatly economized the amount of fuel formerly required. As a result, the modern ocean freight steamship, as a type, is represented by such dimensions and capacities as the following: the *Cevic*, 500 feet long, 9,000 tons capacity; *Prussia*, 445 feet long, 7,000 tons capacity; *Southwark*, 480 feet long, 10,000 tons capacity; and lastly, the *Pennsylvania*, 585 feet long, and 20,000 tons capacity.

The standard steamship of a few years ago carried less than 4,000 tons, required docks and wharves less than 300 feet long, channel depths not exceeding 20 feet, and carried between Europe and the United States 4 tons of freight to each ton of coal expended on motive-power; the steamship of to-day carries 10,000 tons of cargo, demands docks and wharves about 600 feet long, channels 30 feet deep and carries 8 tons of cargo for each ton of coal consumed under her boilers.

The seaports of Boston, New York and Baltimore met these increased demands, and provided, several years ago, longer wharves and increased harbor and channel depths, while Philadelphia waited until her ocean commerce had well-nigh passed to other ports before she awoke to the full realization of the situation. Rival ports that met the demands of modern steamships received the trade and commerce that by position and geographical advantage belonged to Philadelphia, simply upon the principle of the survival of the fittest. We can only exist as a seaport so long as we demonstrate our right to exist, which means that we fully meet the requirements that competition has thrown around the successful operation of the modern steamship and its traffic. When this shall have been done, there is no just reason why we should not soon be able to restore the lost prestige of our port and place it where it properly belongs, the second commercial port of the United States.

After our sleep I believe we are again awake and fully aroused to the exigencies of the times; within one year from

to-day our harbor improvement will be completed, and with it a large number of new docks and wharves fully adjusted to modern steamships, a widened Delaware Avenue; and I dare almost prophesy that within the same year we will have a deep-water channel to the sea, clear and unobstructed. This is our hope and aim, and to such as are here before me we appeal for your encouragement and aid; and while you plan and labor for better streets, purer gas and clearer water, do not forget the need of a better channel to the sea.

PROF. L. M. HAUPT, in response to a request from the President, called attention to the desirability of rapidly improving the depths in the Delaware River. He believed dredging would have to be relied upon mainly for maintenance, and that it would be much more economical, ultimately, to place the material on shore by the improved hydraulic plants now available than to replace it in the river.

He could not endorse the statement in the paper that: "The increased depths which have been obtained by dredging have, in all cases, been permanent, etc.," and cited only a few of the many well-known instances where the facts were decidedly at variance with the statement, as at Kinkora Bar, dredged to over 12 feet, with material placed on opposite bank of stream, which shoaled soon after to 8 feet or less; also at Cherry Island Flats, dredged in 1893 to 26 to 27 feet, shoaled within a month after the completion of contract to 19 to 21 feet; the material, amounting to over 960,000 cubic yards, having been placed on the slope of the flats above the cut. The harbor of the Chesapeake and Delaware Canal Company, at Delaware City, was dredged in July last to 15 feet, but shoaled in about nine weeks to 8 feet, or at the rate of nearly a foot per week from the material now being dumped on the Pea Patch Shoal, just above this point.

Professor Haupt thought it was a mistake to side-track the upper river section of 30 miles of this magnificent waterway with the remark that: "The physical character of this division of the Delaware is such as to render its rectification difficult and very expensive. Its commerce has never been such as to press upon the attention of the Gov-

ernment the need for its extended improvement," since its commerce, over twenty-five years ago, exceeded 4,000,000 tons, and there would seem to be no serious difficulty in securing at least 15 feet at low, or 21 feet at high water.

If any encouragement were given to this river as an outlet to the sea via Raritan Bay, the commerce would, he believed, soon reach or exceed 10,000,000 tons, and effect great economies in transportation and manufactures.

As to the dike question, he preferred high, water-tight structures, believing them to be more effective in regulating the currents, and thought that the policy of improvement, by removal of bars, should begin at the mouth of tidal rivers and proceed up stream, to let in the tidal volume more freely; and he did not wish to be understood as in any way opposed to the rapid prosecution and early completion of the work, but, on the contrary, desired to see everything done to further that result and secure comparative permanency of channel depths.

A MEMBER :—The project for the new harbor improvement in front of the city involved the removal of 16,905,223 cubic yards by dredging; 13,653,075 cubic yards were dumped in the river, and 3,252,148 placed on League Island. What is the status of the large amount placed in the river behind Little Tinicum Island and at Red Bank and opposite Marcus Hook?

L. Y. SCHERMERHORN :—In justice to my convictions and the facts in the case, I cannot remain silent under the criticisms which have been made as to the methods adopted by the Government engineers in carrying on the improvement of our river and harbor, and especially the criticisms relating to the disposal of dredged material. Theory is one thing, but facts are sometimes another, and in this matter the latter are directly opposed to the former. In general terms, the statement has been made that the material dredged from one part of the river is re-deposited in another under such conditions as to permit such material to find its way again into the navigable channels; if such were true, the propriety of the statements to which you have listened would be manifest. That they are not even approximately

true, I know. The improvement which has been accomplished and that which yet remains to be done, for an improved harbor with all of its needed facilities, with a deeper channel between Philadelphia and the sea, has been obtained, and will be carried to final completion through the earnest, intelligent and untiring efforts of public-spirited men, even though handicapped at times by the opposition of a few who have hung, like a mill-stone, upon the neck of the enterprise.

Dumping-grounds, for the deposit of the dredged material, were selected by the Government engineers at localities where, after careful examination, they felt every assurance that it could not result in an injury to the main ship channels. Not satisfied with resting such assurance upon theory, repeated surveys have since been made of these places of deposit, and, as a result, it is found that their anticipations were in all cases correct, and that the material placed in these dumping-grounds has remained therein within very narrow limits, and not, as here stated and elsewhere sometimes asserted, washed again into the navigable channels. This is as true of the Cherry Island dump as of the others, and, while admitting that the channel dredged at the last-named locality a few years ago has shoaled, it has nevertheless shoaled from causes outside of the dumping-ground question.

In reply to the query, "what is the status of the large amount of material placed in the river behind Tinicum Island, at Red Bank and opposite Marcus Hook?" I would say that at these localities has been deposited, without injury to the river, the larger part of the material removed from Philadelphia harbor and not placed ashore. From time to time surveys have been made of these dumping-grounds, and their results show that the material deposited therein has remained where it was originally placed.

For several years, all material dredged from the bars of the river was placed ashore, at greatly increased cost, and as is now being advocated by Prof. Haupt; and yet, during and following such a method, these same channels re-shoaled at a rate not one whit less than that which had previously

existed; and yet, we are told that former methods, which proved unsuccessful, should again be adopted as a panacea for the same evil. I am glad to say that such adverse criticism has had but a small following. The leading commercial and maritime bodies of our city have reason to hold in high estimation the judgment of the Government engineers, and have repeatedly declared their faith in the propriety of their methods. The judgment of these bodies has been founded on fact, and I have very briefly attempted to place such before you; at all events, I feel assured that what I have stated is fact, and not imagination or theory.

Mr. Edwin F. Smith, M. Am. Soc. C. E.:—A deep-water channel to the sea is a matter of the greatest importance to the city of Philadelphia. Situated as the city is, 120 miles inland on a tidal stream, she will be placed at a disadvantage in her commercial relations with foreign countries as long as the largest vessels cannot have perfect freedom of movement to and from her wharves.

Early in the century, Philadelphia enjoyed the proud distinction of being in the front rank among American cities in the magnitude and importance of her commerce. Her ships were to be seen in every quarter of the globe, and to the enterprise of her merchants in those days, more than to any other one thing, is to be attributed her growth and development into the largest manufacturing center, and the third city in population, in the Union to-day.

But with the enlargement of the transportation facilities of the country, the multiplication of transcontinental trunk lines, and the employment of vessels of deeper draught and larger carrying capacity in foreign commerce, there has come about a change in the relative position of Philadelphia, and her foreign trade has been gradually slipping away from her grasp.

Boston, New York, Baltimore, Norfolk, and even New Orleans and Galveston, are reaching out for the tempting prize of commercial supremacy through the avenue of deeper channels to the sea.

New York has 30 feet depth of channel at mean low water, and Baltimore is now working for the same maximum

depth. The mouth of the Mississippi River was long ago improved by the Government by the building of the Eads jetties, and the depth over the bar at Galveston has been increased so that vessels of deep draught can enter that port. The railroad and other facilities at these Southern ports for the prompt and economical trans-shipment of freight directly from the cars on the wharf, or from elevators, have kept pace with the harbor improvements, and to-day are drawing trade away from the Northern ports.

I have been deeply interested in the paper which has just been read by Mr. Atlee, and in its discussion by Mr. Schermerhorn and Prof. Haupt, and can really add but little to what has been said.

Nevertheless, there are two important divisions into which this subject may be divided, namely:

(1) The depth of channel which it is possible to attain.

(2) The means to be adopted to maintain that depth.

As bearing on the first proposition, I quote from the Report of the Board of United States Engineers, for the year 1894:

"The present, and probably ultimate, greatest available depth that can be maintained for the navigation of the Delaware River is *about 27 or 28 feet* at mean low water. For long stretches of many miles of main channel the existing and possible depths do not exceed this, while the actual draught required for the commerce of the river is in excess of 25 feet."

In the light of the facts before us, no such depth of channel as 27 feet at mean low water will answer for the Delaware River if Philadelphia is to retain her fair share of the commerce of the country.

In proof of this fact, we have this warning from Mr. Higbee, of the International Company, who has said, recently:

"Most of the company's vessels *can be loaded to a draught that cannot be navigated in the Delaware River*, and the problem was reduced to making the draught as light as possible with the best cargo. Vessels are now loading to a draught of 26 feet. The International Line vessels could be loaded 27 feet."

As there is less than 20 feet depth at mean low water over portions of Cherry Island Flats, we can easily understand why it has been necessary for the International Company to withdraw its largest freighters, the *Kensington* and *Southwark*, from Philadelphia and place them at New York.

I am impressed with the belief that every effort should, for the present, be directed to obtaining a depth of 27½ or 28 feet, at mean low water, and later on, if possible, 30 feet. The latter I know would be a difficult and costly undertaking, as is evident from an inspection of the profile of the bed of the river; but when we consider such works as the Manchester Ship Canal, and the removal of that ancient barrier, the Iron Gates of the Danube, just accomplished, I think we need not shrink from undertaking any improvement that has been suggested for the Delaware.

As to the means to be employed for accomplishing the work, I may say that, from long experience with the improvement of river channels on a smaller scale, I am a firm believer in the efficacy of dikes in maintaining a given depth.

They should, however, be carried up at least to the level of high water, if not above. Dikes built to low water only do not sufficiently contract the tidal currents, nor give the maximum of scouring effect. This would appear to be the situation at Dan Baker Shoals.

The width of channel in such cases, also, should be sufficient for the free movement of vessels of the largest class, for which purpose a width of 1,000 feet would seem to be necessary. Mr. Cramp has alluded to the possibility of trouble with ice in the channel between dikes, but I think this might all be overcome by the use of larger and more powerful ice-boats, of a different pattern than those now in use, as is now the practice on the Great Lakes.

Another means of accomplishing the end is by dredging, and much has already been done, both by the United States and by the city of Philadelphia, in the removal of the islands in front of the city, and in deepening the channels at the six principal locations below Philadelphia, named by Mr. Atlee.

At some of these locations, notably Cherry Island Flats, continual dredging will be necessary in order to maintain a channel, and the deeper the channel the more difficult it will be to maintain it.

This being the case, the necessity of confining the depositing of dredged material to locations from which it will surely not reach any part of the navigable channel is apparent. There will always be a large annual amount of dredging work to be done in the Delaware River, and hence the necessity for making the best possible disposition of the material.

I am glad to hear reference made to the fact that the improvement of the navigable channels of our great rivers is of national and not merely local importance. Certainly, the whole nation is interested in the navigation of the Great Lakes, and of the Mississippi, the Ohio, the Hudson, the Delaware and other rivers upon which there is a considerable volume of traffic. Each section of this vast country has its own peculiar needs for Government aid in public works, and no one section should look with disfavor on an expenditure in another, when it is for the public good.

I am glad, too, to see so great interest taken in the agitation of this question, and shall hope to see it continue, until the harbor of Philadelphia shall be as easy of access from the sea as any port in the country.

PROF. HAUPT, in view of the fact that certain matters appear in the printed copy of this discussion, which were not presented at the meeting, submits the following supplementary statements :

Mr. Schermerhorn states that if it were true "that material dredged from one part of the river is re-deposited in another under such conditions as to permit such material to find its way again into the navigable channel, the propriety of the statements (made by the writer and others) would be manifest." He adds that these statements are not even approximately true, and says : "These same channels re-shoaled at a rate not one whit less than that which had previously existed."

Now as to the facts: The official report of the United States

Government states very clearly, on page 1,023, Report for 1895, in speaking of the channel at Cherry Island Flats: "The formation of a channel west of the flats, having a width of 470 feet and a depth of 24 feet M.L.W., was commenced in 1879 and completed in 1884, the length of the cut being nearly 2 miles. In this work 1,594,740 cubic yards of material were removed by dredging at a cost of $400,000." (This was placed on shore by handling twice, hauling over the flats on trains, dumping and spreading, at an average cost of less than 25 cents per yard.) Previous reports state that the cut shoaled very slowly, and this report (1895) remarks that "an examination made in May, 1892, showed that the channel had shoaled about 1·2 feet over a distance of about 10,000 feet." (That is in the eight years (1884–92) the shoaling had been about 14 inches or *less than 2 inches a year.*) The report adds:

"In 1893 the channel was dredged over a width of 400 feet, and to a depth of from 25 to 27 feet, M.L.W. Soon after the completion of the work,* the channel shoaled to a depth of from 19 to 21 feet over the width dredged, for a distance of about 4,000 feet, but the material is very soft and has not obstructed the passage of vessels."†

This contract was let to the American Dredging Company, which was permitted to deposit the spoils about a mile above the cut on the slope of the flats, and the examination was made within a month after the completion of the contract, with the astonishing results thus officially vouched for, viz.: That it had shoaled from 25 to 19 or from 27 to 21 feet in so short a time as a few months—*six feet*, as compared with the previous rate of less than *two inches* in a year. In view of these facts, how are we to interpret the statement that the rate is not one whit less than before?

There can be but one conclusion, yet we are told that this shoaling came from *other* sources, although there was no deposit made in the river at or near this cut at that time, and the dump was observed by pilots to disappear rapidly,

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* October 29, 1893.

† What can this mean?

as averred by their statements relative to their ability to sail their vessels over the dumping ground a short time after the deposits were made. Mr. Schermerhorn, President American Dredging Company, attempts to explain this by the comprehensive but unsatisfactory statement that "it shoaled from causes outside of the dumping-ground question," but he does not enlighten us as to their causes nor their origin, as they did not exist before.

Upon the general question of the re-formation of shoals from material dumped back into the river and not restrained by dikes, a special board of United States Engineers, appointed to consider this very problem, says: "The action of the currents upon the ordinary materials dredged and re-deposited, as on sand and mud, is to at once redistribute them. The use of dumping scows, dumping in from 7 to 11 feet of water, would, in effect, place the dredgings upon the channel slopes and insure their being immediately transported to other points possessing no excess of depth."

"To the improvement of Cherry Island Flats these considerations have special reference, etc." * * * "The Board is unanimously of the opinion that such action (dumping in the river either by the United States or others) would be prejudicial to navigation."

And with reference to the site recently selected for the deposition of over 1,200,000 cubic yards on the western slope of Pea Patch Island at Fort Delaware, the same Board says: "It has already an insufficient depth and no dumping should be done in it."

The effect of dumping here was so marked that, in response to the protest of the citizens of Delaware to Senator Gray, it appears to have been suspended, and the scows are now discharging on the Goose Island Flats below the Finn's Point jetty. The Superintendent of the Chesapeake and Delaware Canal wrote, October 17, that their harbor was dredged, by themselves, to 15 feet M.L.W. on July 31. "To-day we have about 8 feet," from a survey made ten days ago, and confirmed by that made "by the Government Engineers this week." "Such a rapid filling up has never before occurred." "It is caused by the vast amount of mud

the contractors have been dumping in our immediate neighborhood."

Again, the League Island docks shoaled to the extent of 50,000 yards in nine months, while the obstructions back of Tinicum and in front of the former Lazaretto are reported to have been washed away by the currents, and to have gone out into the river. These and many other facts might be stated on credible authority to confirm the position taken by the Board of United States Engineers and others, as well as by the writer, as to the injury to the river and delays in securing results in our efforts to obtain a deep water-way to the sea.

The following contributions to the discussion have been received by the Secretary of the Institute in correspondence:

MR. CHAS. H. CRAMP:—The paper offered by Mr. Atlee is a valuable and interesting contribution to the literature of the subject—the improvement of the Delaware River and the harbor of Philadelphia.

It is the most complete *résumé* of the legislative and executive history of the scheme that I have seen.

So far as it touches upon the civil engineering problems involved, it is beyond criticism.

There is, however, one problem which I have not seen discussed in any of the numerous papers and reports upon the subject that have come to my notice.

That is the ice problem, and, from the standpoint of practical experience, which is naturally my point of view, that is one of the most serious difficulties to be dealt with.

At best, a tidal river is a difficult thing to deal with in hydraulic engineering, and the difficulty is greatly increased and complicated when large masses or fields of ice are encountered on its surface nearly every season.

Under such conditions, the deepening of a channel for navigation forms only part of the necessary provision. In addition to this, the natural, or undeepened, part of the river should be kept free from surface obstructions that will intercept the flow of water, whether it is coming in or going

out of the whole tidal system, keeping in view at all times that the greater the volume of water that enters the system the larger or greater the amount that goes out, thereby promoting any necessary scouring the proposed channel may need.

These surface obstructions prevent the free passage of ice fields, which form rapidly on the surface when the temperature falls to 20° or below. We all know that the wider the surface the more easily the fields pass out to the sea.

For these reasons I would object generally to high-water dikes or jetties, and would also suggest the least possible narrowing of the river itself, as distinguished from the channel proper.

High-water jetties, with sharp, boat-shaped ends, when run in the direction of the river, are not so objectionable.

I offer this in a suggestive, rather than in an argumentative way. In fact, I assume that, while no mention has been made of this branch of the subject in any published matter that I have seen, it has received the attention of the engineers in their own discussions and calculations.

The general channel scheme, so clearly described by Mr. Atlee, is comprehensive and excellent. But I would consider it only a good beginning; 26 feet depth and a mean width of 700 feet is not enough for the up-to-date requirements of our heavy commerce and shipbuilding necessities, to say nothing of the probable developments of the near future.

We have already seen the large new freighters of the International Company (the *Kensington* and *Southwark*) forced to cease plying to this port. The Cramp Company has, in the past ten years, built ten vessels for the navy and several large merchant and passenger ships, including the *St. Louis* and *St. Paul*, which required two tides to get up or down the river at normal draught; and, even at that, some of them have dragged in the mud at various points not by any means the worst, when they happened to be caught there at any stage of water less than mean high.

For safe and sure navigation a ship should always have some clear water—at least 2 feet—under her keel. She

should also have width at least equal to twice her length for any emergency, such as impending collision with a sailing vessel, that might require turning or a quick sheer out of her course.

Twenty-six feet by 700 feet will not afford these conditions to all ships that would like to ply to this port, or are likely to be built here.

Thirty feet by 1,500 feet would be nearer the mark of the actual present requirements of the commerce and industries of Philadelphia, and such dimensions of channel will be crowded to their utmost capacity by the development of the near future.

I have noticed in the current discussions of this subject by prominent men and the newspapers of Philadelphia, though I see none of it in the paper of Mr. Atlee—which is purely historical and technical—a tendency to what I consider an undue and possibly injurious exploitation of the purely local advantages which Philadelphia alone is to derive from the perfection of the proposed scheme of river and harbor improvement.

For my part, whenever I have had occasion to offer argument or suggestion in favor of the improvement, I have based it upon broad and general commercial grounds, viewing the benefit to Philadelphia in particular as incidental or consequential thereto.

It is true that Philadelphia is a very great commercial city, and that her interests will be subserved by improvement of navigation upon the Delaware and the consequent enlargement of her commercial facilities; but that is not the only reason why these things should be done, and, in fact, it is not the main reason.

Whatever conduces to the enlargement of the commercial facilities of Philadelphia benefits alike the people of a very wide area of country, which includes Delaware and New Jersey. Therefore, everything which conduces to enlarge her facilities as an entrepot, must confer benefits in all directions tributary to the river and the bay.

If Philadelphia were not here there would be no occasion for the proposed improvements; the presence of the city

here makes the improvements necessary to the general commercial welfare and prosperity of the American people. In other words, I might say that Philadelphia is the cause of the improvements; the improvements are not the cause of Philadelphia.

If I had time I would go into particulars, illustrating, for example, by the fact that the wealth of the State of Delaware is, so far as her population and resources go, in every square of her towns and in every acre of her agricultural area, equally interested with Philadelphia in the proposed improvements. This fact is so apparent that I do not consider it necessary to amplify upon the statement. The logic of it may be applied generally to New Jersey and all other localities which employ or would employ Philadelphia as a channel through which to conduct commercial intercourse with the outside world, or whose development is in any way associated with or contingent upon the improvements of Philadelphia.

As I have already intimated, even if there ever were valid arguments against the establishment of great commercial entrepot on the site of this city, the time for their advancement has long since past, and it is too late to discuss that class of questions. The city is here, and the growth of two centuries has created interests and established a foothold which must be permanent; anything that would tend to impair the foothold or imperil these interests would be as disastrous to the whole region as it would be to the city itself.

The problem is to deal in the most effective and permanent manner with the difficulties which exist, and to remove any obstacles that may be in the way of the best and widest realization upon the basis of things as they are. For these reasons it would afford me great pleasure to see a broader and more thoroughly national scope given to the advocacy of these great improvements than I have seen in previous discussions. Of course, as I said at the outset, Mr. Atlee's paper does not itself invite this class of suggestions.

With regard to the proposed extension of the main ship channel from its present southerly termination to connect

with the channel below, thereby opening the southern water-front of the city from Greenwich Point down, to commercial uses, I remark that the desirability of its completion from every point of view is too obvious for comment.

The only suggestion I would offer in these premises is to repeat the previous one, namely, that whatever may be done in this direction should be done without the erection of any fixed obstructions in the river—using the word "river" here, as heretofore, to embrace the whole sheet of water and not the channel alone.

If this scheme is carried out logically, it is suggested that the removal of certain existing obstructions, such as Greenwich Point and certain islands in the river and bay below, would be necessary.

In conclusion, I would remark that whatever may be the scheme at any point in the region of improvement, it should be based upon the principle of providing for the most copious and least obstructed inflow and outflow of water under natural conditions.

Care should be taken to facilitate as much as possible the exit and the breaking-up of ice-fields, thereby shortening the period of danger to navigation from that cause, if not averting it altogether.

When the total benefit, or, perhaps, it would be better to say the total national profit, to accrue from these improvements in the long run is considered, any question of immediate cost becomes immaterial.

J. R. SELFRIDGE, Lieutenant-Commander, U. S. N. (late in charge of the Branch Hydrographic Office at Philadelphia):—* * * I trust, in the discussion which follows, a plan for the formation of a Board of River Commissioners will be suggested, in which the interest of all branches of the marine profession will be represented.

In my opinion, it should be composed of five members, as follows:

Two gentlemen most widely known and respected in marine circles.

One civil engineer.

One army officer, of the engineers.

One naval officer, presumably the inspector of the lighthouse district.

The appointment of the latter is essential, in view of the importance of a sufficient water-course for our battleships, and the selection of the officer most acquainted with the changes in the hydrography of the river. The naval inspector of lighthouse for the district seems appropriate.

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WASHINGTON, D. C., October 19, 1896.

MR. E. R. SHARWOOD, Secretary, The Philadelphia Maritime Exchange:—* * * Referring to your valued favor of the 24th Oct., * * * in which you do this Exchange the honor to suggest that any contribution from it upon the subject of Mr. Walter Atlee's address on the improvement of the channel of the Delaware River before the Institute, on Wednesday, October 21st, would be acceptable for printing in the *Journal of the Institute*, in connection with the proceedings of the meeting, I have the honor to hand you herewith copy of preamble and resolutions unanimously adopted at a special meeting of our Board of Directors, on October 15, 1896, and also a copy of a resolution of confidence passed by the Joint Executive Committee on the Improvement of the Harbor of Philadelphia and Delaware and Schuylkill Rivers, of which this Exchange is a member, adopted May 11, 1896.

It is unnecessary for me to add that this Exchange is very deeply interested in the improvement of the Delaware River, and has given much time and thought to the subject.

THE PHILADELPHIA MARITIME EXCHANGE,
PHILADELPHIA, October 30, 1896.

At a special meeting of the Board of Directors of The Philadelphia Maritime Exchange, held the 15th day of October, 1896, the following preamble and resolutions were unanimously adopted:

Whereas, The welfare of the maritime and commercial interests of the port of Philadelphia is intimately connected with the improvement of the channel of the Delaware River at both Schooner Ledge and Cherry Island Flats; and

Whereas, The early completion of these improvements might be delayed, if value were given to the criticism which has been made of the present method of disposing of material dredged from these channels; and

Whereas, The experience of the past justly entitles the plans and methods of the United States Engineer Department to be received with the highest confidence; therefore,

Resolved, That The Philadelphia Maritime Exchange protests against the unwarranted criticism and censure of the methods of the Government in carrying on these improvements, and reasserts its confidence in the propriety and success of the plans which are in operation for the improvement of the localities named.

Resolved, That a copy of this action of The Philadelphia Maritime Exchange be transmitted to the Secretary of War and to Major C. W. Raymond, Corps of Engineers, U. S. A.

PHILADELPHIA, October 15, 1896.

Resolution of confidence by the Joint Executive Committee above named in the skill and ability of the U. S. Engineer officer in charge of Delaware River improvement:

Resolved, By the Joint Executive Committee on the Improvement of the Harbor of Philadelphia and the Delaware and Schuylkill Rivers, consisting of representatives of the Philadelphia Board of Trade, Philadelphia Commercial Exchange, The Philadelphia Maritime Exchange, Philadelphia Drug Exchange, Grocers' and Importers' Exchange, Vessel Owners' and Captains' Association, Board of Port Wardens, Manufacturers' Club and Board of Harbor Commissioners:

(1) That we seriously deprecate the criticisms upon the United States Engineers which have recently been referred to in some of the newspapers in their discussion of the River and Harbor Bill now pending in Congress, which criticisms we believe to be unfounded in fact and unauthorized by any proper engineering authority:

(2) That the commercial and maritime organizations of Philadelphia hereby renew their expression of confidence in the skill and ability of Major C. W. Raymond, U. S. Corps

of Engineers in charge of this district, and also their confidence in the plans, repeatedly framed, extended and approved by the engineers of the War Department since 1885, under which the work of improving the navigation of the Delaware River is being conducted; and that they consider the work already done under these plans as eminently satisfactory in its results.

PHILADELPHIA, May 11, 1896.

MR. FRANK J. FIRTH, President, The Erie and Western Transportation Company:—* * * There is no doubt that the city of Philadelphia will continue to be at a commercial disadvantage in its effort to share in the export and import trade with competing seaboard cities until it can command as cheap ocean service as they do. This cheap ocean service cannot be had until the Delaware River offers a channel not less than 26 feet deep on minimum low water, thus enabling large modern vessels, drawing, say, 30 feet, to pass in and out freely on high water.

The work of improving the channel is now under contract to an extent that, it is understood, will insure the full depth of water required to a point, say, 48 miles below the city, early in 1897. The work is in the care of engineers of the United States Government, and it certainly would be a grave misfortune if the progress of the work should be checked by any discussion or differences of opinion among our citizens or commercial bodies as to the particular form of dredge to be used on the work, or whether the material removed should be deposited on shore or in suitable places in the river. Citizens of Philadelphia, interested in the growth of its foreign and coastwise trade, will do well to concentrate their efforts on urging the promptest possible completion of the channel improvement, leaving the engineering details with the U.S. Government Engineers, where they properly belong.

PHILADELPHIA, October 30, 1896.

MR. WM. R. TUCKER, Secretary, Philadelphia Board of Trade:—* * * Since the year 1874 I have taken a deep interest in the improvement of the Delaware River, and have been intimately associated with all the efforts made

by the commercial and maritime interests of Philadelphia to impress upon Congress the vital importance of appropriating such amounts as would permit the removal of the shoals obstructing the safe and speedy navigation of vessels of the deepest draught between this port and the sea. I have therefore read, with more than ordinary interest, Mr. Atlee's able review of the work upon the ship channel, and I heartily endorse his words of commendation for the United States Engineers, when he says: "The extent of the improvement of the natural channel of the river, which has been accomplished during the last ten years, is greater than that obtained during an equal interval of time upon any river at all approximating the Delaware," and "that which has been accomplished is an admirable tribute to the means which have been employed and the skill which has directed these means," ending up with the none too great compliment that "to a continuance of this skill and the methods of the past must we look for the final successful improvement of the Delaware River."

During the early stages of the work of the removal of Smith and Windmill Islands, the amateur hydrographers and encyclopædic engineers were pleased to burden the public prints with continued criticisms as to the plans of the engineer in charge of the work, and asserted and re-asserted that the removal of the islands would increase the cross-section of the river abreast of the city, and would prevent the maintenance of the depths secured, unless solid piers should be constructed simultaneously with the removal of the islands. Fortunately, at that time little attention was given these theorists; for we are now told by Mr. Atlee that "the increased depths which have been obtained by dredging have, *in all cases*, been permanent, even over the sites of Smith and Windmill Islands; where temporary deposits might have been apprehended, *there is no indication of shoaling*."

Mr. Atlee adds: "These deductions are derived from repeated surveys of the deepened areas, and from an experience covering active dredging operations extending over an interval of nearly four years."

The criticisms which have appeared for some time past as to the plans of the United States Engineer Department for conducting the work of improvement upon our rivers are to be regretted. * * *

The Joint Executive Committee on the Improvement of the Harbor and the Delaware and Schuylkill Rivers, representing the trade, commercial and maritime associations of Philadelphia, has placed itself upon record as having entire "confidence in the plans, repeatedly framed, extended and approved by the Engineers of the War Department since 1885, under which the work of improving the navigation of the Delaware River is being conducted, and that they consider the work already done under these plans as eminently satisfactory in its results."

The Board of Trade and Maritime Exchange have quite recently endorsed the joint committee in commending the plans and work of the Government Engineers.

The following is a copy of the preamble and resolutions unanimously adopted by the Philadelphia Board of Trade, at a meeting held on October 19, 1896:

Whereas, The success of Philadelphia as a commercial port is largely dependent upon the earliest improvement of the navigation of the Delaware Bay and River; and

Whereas, It is believed that the United States Engineer Department is fully alive to the great importance of completing the work of the said improvement, and has adopted engineering methods calculated to secure the best and quickest results for the amelioration of the conditions so unfavorably affecting Philadelphia as a seaport; and

Whereas, The highest confidence is entertained in the ability and integrity of purpose of the United States Engineers—a confidence warranted by the experience of the past; therefore,

Resolved, That the Philadelphia Board of Trade deprecates the unwarranted criticisms of the plans of the United States Engineers for carrying on the improvement of the channel-way of the Delaware Bay and River, having every confidence in the wisdom and ultimate success of their methods and plans.

Resolved, That a copy of the foregoing be transmitted to the Secretary of War and Major C. W. Raymond, Corps of Engineers, United States Army.

PHILADELPHIA, November 2, 1896.

ON THE ORIGIN OF ATMOSPHERIC OXYGEN.

TWO NOTES ADDRESSED TO THE ACADEMY OF SCIENCES.

By T. L. PHIPSON.

Translated by Chief Engineer Isherwood, U. S. Navy.

First Note. *Comptes Rendus*, 1893, p. 309.

I ask permission to present to the Academy the results of some experiments made during the last few years, relative to the chemical composition of the terrestrial atmosphere.

That the primitive atmosphere did not contain free oxygen may be accepted as certain, since sulphur and graphite—combustible substances—are found in the primitive rocks. Dr. Koene, who was for many years Professor of Chemistry in the University of Brussels, says that after the period of intense heat had passed, the atmosphere contained only nitrogen and carbonic acid, the proportions of which gradually diminished as the proportion of oxygen gradually increased.

I desired to ascertain how the plants of the present time were affected in an atmosphere of nitrogen gas, in an atmosphere of carbonic acid gas, in an atmosphere formed by a mixture of these two gases, and in an atmosphere of hydrogen gas. The experiments were made on plants of the genera Poa, Agrostis, Trifolium, Myosotis, Anthirrhinum and Convolvulus. Of all these plants, the Convolvulus arvensis is the best adapted for this kind of experiment, be-

cause of the smallness of its size and the rapidity of its growth.

I have elsewhere (*Chemical News*, 1883) stated ten years ago that microscopic plants (Protococcus pluvialis and P. palustris) vegetating in spring water can be transformed, so to speak, into veritable genera tors of oxygen gas.

My observations relative to this interesting subject have been published in the *Chemical News*, of London (June and July, 1893). In these experiments the roots of the plants—immersed either in a fertile soil or in water containing free carbonic acid, and thus exposed to all the substances necessary for vegetating—were kept in the dark, while the upper part of the plant was exposed to a northern light in a graduated inverted glass bell. The daily temperature varied during the experiments from 15° to 26° C.

I ascertained that the plants could live in carbonic acid, but they did not in the least thrive. In hydrogen the vegetating was less backward, but the hydrogen was gradually absorbed (burned by the oxygen secreted by the plant), and after a few weeks it had nearly disappeared. In nitrogen the Convolvulus arvensis can live a long time if the water employed in place of a rich soil is kept supplied with free carbonic acid. In a mixture of two-thirds nitrogen and one-third carbonic acid, the vegetation thrives well, and the composition of the atmosphere resulting after several weeks closely resembles that of our own, and without change of volume.

If the primitive ages of the globe be considered, there must be conceded, and many scientists do so concede, that the high temperature then existing would have prevented the formation of any chemical compound whatever, the matter of the globe being at that time in the state of free atoms; but in measure as the earth cooled, the elements combined according to the laws of chemical affinity, until, finally, the surface of the earth remained covered by an atmosphere of nitrogen gas only, a substance having no tendency to combine directly with other substances. Now, into this primitive atmosphere of nitrogen gas, vegetables have discharged oxygen gas during an incalculable period

of time, until the air has attained its present composition. The oxygen of our air is thus a result of vegetable life (which latter had necessarily to precede animal life). The carbonic acid gas appropriated by the vegetables must be regarded as a volcanic production.

The primitive atmosphere of nitrogen gas was, without doubt, and owing to volcanic action, richer in carbonic acid than the atmosphere of the present day.

Second Note. *Comptes Rendus*, 1894, p. 444.

Since the publication of my first note (*Comptes Rendus*, 1893, p. 309) I have made a number of new observations, which I have now the honor to place before the Academy.

In my first note I assumed the primitive atmosphere of the earth to have been composed principally of nitrogen, a gas which has only slight tendencies to combine with other substances; and that volcanic action supplied carbonic acid to the land, to the water and to the atmosphere.

Into this atmosphere of nitrogen, carbonic acid and aqueous vapor, the primitive plants discharged oxygen gas, the relative quantity of which has continuously increased from the first appearance of vegetable life.

My experiments, made with a great number of plants of the present day, vegetating in an artificially prepared primitive atmosphere, show that these plants are essentially anærobic; that is to say, they can live without free oxygen. Thus, the Convolvulus arvensis, for example, vegetating during three months in an atmosphere composed of humid nitrogen and a certain proportion of carbonic acid, converted this atmosphere into oxygenated air such as exists to-day; and if the experiment be continued sufficiently long, the air in my graduated inverted bells becomes richer in oxygen than our present atmosphere.

The first plants which appeared upon the land and in the waters of the earth were the inferior ones. Now, my experiments show that these inferior plants, these Protococcus, Conferva, Ulva, etc., discharge, weight for weight, much more oxygen in a given time than the superior ones. For example, I found that in one experiment the unicellular

Algues gave at least five times more oxygen than the avicular Polygonum.

It may easily be conceived that in measure as the anærobic cellule of the primitive plants was immersed in an atmosphere continuously becoming richer in oxygen, this cellule underwent continuous modification, until at the end of cycles the ærobic cellule was finally produced, a cellule which discharges carbonic acid instead of oxygen into the atmosphere. In this manner I explain the slow and gradual production of animal life.

My researches on this subject have been published in the *Chemical News*, of London, during the years 1893 and 1894 (4 volumes). In this note I can give only a mere sketch of the new theory to which my observations have led me. These publications had, for object, the following:

(1) That in the remotest geological periods, nitrogen formed, as it forms to-day, the principal part of the earth's atmosphere.

(2) That the presence of free oxygen in this atmosphere is wholly due to vegetation; and that the primitive plants were the means employed by nature to supply the air with that gas.

(3) That the plants of the present day, like those of the oldest geological evolutions, are essentially anærobic.

(4) That in measure as the proportion of free oxygen in the atmosphere continuously increased during the course of cycles, the anærobic cellule became less and less anærobic (mushrooms, ferments, bacteria), and finally completely ærobic (animal life).

(5) That even at the present time the most inferior unicellular Algues give, weight for weight, much more oxygen to the atmosphere than the superior plants.

(6) That in measure as the proportion of free oxygen in the atmosphere has continuously increased during the past long geological ages, the nervous cerebro-spinal system, the highest characteristic of animality, has continuously developed as paleontological investigations show.

BALZER'S DEVICE FOR MAKING MILLING-CUTTERS.

[*Being the report of the Institute, through its Committee on Science and the Arts, on the invention of Stephen M. Balzer.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 28, 1896.

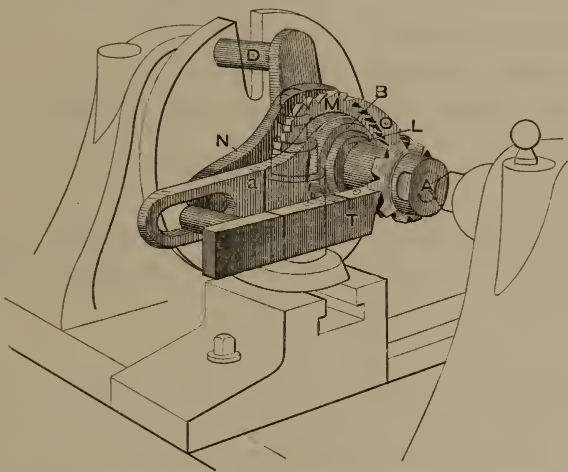
The Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating Balzer's device for making milling-cutters, reports as follows:

This device is an apparatus designed to be mounted between the centers of an ordinary lathe for the purpose of forming and at the same time backing off the teeth of milling-cutters.

As shown in United States letters-patent No. 535,127, dated March 5, 1895, issued to S. M. Balzer, copies of which were submitted by the applicant, it may be briefly described as follows:

A steel spindle, with a recessed center at each end to receive the centers of the lathe, and a projecting arm provided with a pin to engage the slot in the face-plate, carries a hollow steel spindle or sleeve, which is provided with collars and clamp-nuts to hold the cutter blank to be operated upon. The center recesses at the ends of the spindle are placed eccentric to its axis, so that when the spindle is rotated the sleeve carrying the cutter, if prevented from rotating, is given a lateral motion to and from the tool-post. This sleeve is provided with a gear-wheel, fixed to it at the end next the face-plate, and also carries a similar gear-wheel mounted loosely upon it and in contact with the first wheel. These are differential wheels, the first having, say, sixty teeth, and the second, say, fifty-six teeth. Meshing with both these wheels is a pinion carried on a projection of the pin that engages with the face-plate. The second, or loose wheel, is prevented from turning by a projecting arm resting on the tool-rest.

The result of this arrangement is that when the lathe is set in motion, the revolution of the pinion around the two differential wheels causes the wheel fixed to the cutter-sleeve to make a part of a revolution, while the eccentricity of the spindle causes the sleeve and cutter to move toward the tool-post at the same time. A hardened steel shaping tool being firmly fixed in the tool-post, the result is a cut off the top or back of the tooth, gradually going deeper as the cutter advances. The cutter then recedes and advances again at the next revolution of the lathe for the next tooth. The degree of rotation of the cutter is determined by the relative number of teeth in the differential wheels, and may



be varied at pleasure by changing the wheels. It was found in practice that the unavoidable back-lash in these wheels caused the forming tool to chatter objectionably, and to avoid this a ratchet-wheel was substituted for the fixed wheel and a lever and pawl for the loose wheel. The result is entirely satisfactory, the machine working with great steadiness and precision. A number of practical tests were made with uniformly good success. The teeth made in this way may be sharpened by grinding on their faces without in the least altering their shape, until they are entirely worn out, and in this and other respects they are fully equal to cutters made by the expensive special

machines in general use. There is no other such device on the market, so far as is known.

The claim of the inventor of having produced a "cheap and effective device, capable of use in an ordinary lathe, by means of which milling-cutters or similar tools may be readily made," is fully borne out; and for the ingenuity and skill displayed therein, the Franklin Institute recommends the award to Stephen M. Balzer, of New York City, N. Y., of the John Scott Legacy Premium and Medal.

Adopted at the stated meeting of the Committee on Science and the Arts, April 8, 1896.

JOSEPH M. WILSON, *President.*
WM. H. WAHL, *Secretary.*

G. MORGAN ELDRIDGE,
Chairman, Committee on Science and the Arts.

Award confirmed by the Board of Directors of City Trusts.

THE STANDARD OF EFFICIENCY FOR STEAM-ENGINES AND OTHER HEAT-MOTORS.

BY R. H. THURSTON.

A Standard of Efficiency by which to measure the thermodynamic value of the steam-engine and other heat-motors, in their exceedingly various types and forms, is constantly required by the engineer, and the general adoption of a common and correct standard is one of the desirable conventions in all thermodynamic work. A number of standards, in themselves accurate and scientifically available and acceptable, have been proposed, and the question to be settled by common consent is: What one of the various possible standards shall be adopted?*

The Essentials of a Satisfactory Standard are:

(1) Ideal perfection and accuracy.

(2) Invariability under the conditions of its employment.

* See paper by Capt. H. R. Sankey, "The Thermal Efficiency of Steam-Engines;" Proc. B. Inst. C. E., March 24, 1896, p. 182.

(3) Convenience.

(4) Special suitability to the class of values which it is to measure.

Where, as is often the case, a number of possible standards are available, all having a common measure and fixed relations among themselves, that one will be chosen which presents the best combination of precise measures for use in the class of problems to which it is to be applied.

Heat-Engines, of whatever class, type or form, are employed simply to convert thermal energy into useful dynamic energy, and their efficiency is therefore measured by the ratio of the amount of energy thus rendered available to the quantity of energy originally supplied for transformation. From this point of view two measures of efficiency are at once seen to be available, and two standards are offered for choice. Both of the latter are absolute and invariable for any given case; but only one is absolute and invariable without qualification. The latter is the measure of the thermodynamic equivalent of the respective energies; the other is the measure of the maximum ideal conversion-ratio of the most perfect possible thermodynamic cycle. The one is unity of absolute efficiency, the other the quantity measuring the ratio of thermodynamic transformation of the Carnot cycle, $(T_1 - T_2) / T_1$, which ratio may be taken as the standard and as the unit of comparison for any other thermodynamic cycle, or for either the ideal or the real engine.

Efficiency Unity, taken as a Standard, infers complete transformation of all heat supplied into mechanical energy, *i. e.*, for example, perfect thermodynamic conversion of the British thermal unit of energy into 778 foot-pounds of dynamic energy, or 427 kilograms per calorie. It is in this measure that the efficiencies of the Carnot, as of all purely thermodynamic, cycles is measured. Thus gauged, the Carnot cycle, for example, within the usual maximum range of temperature of our steam-engines to-day, has an efficiency of about 30 per cent. This is evidently available as the ultimate and the universal standard for all thermodynamic operations.

The Carnot Efficiency, taken as a Standard, gives a measure of the economic relation of any thermodynamic cycle to the maximum ideal efficiency of all heat-engines, whatever the character of the working fluid adopted. It may be taken as unity in such cases, and the relation thus gauged is as absolute and accurate as the preceding, within its defined limitations. It permits the comparison of the measured efficiency of any heat-engine with that of the perfect engine within similar temperature range. It must obviously be carefully distinguished from the standard of perfect thermodynamic transformation-efficiency, unity. The Carnot Efficiency is a standard proposed and advocated by many authorities. It is not an absolute standard in a proper sense, since its limits are not fixed.

The Efficiency of any Chosen Ideal Thermodynamic Cycle is a standard adopted in many cases, and occasionally advocated as the unit of reference. It measures, when thus taken as the unit of efficiency, the relation of the thermodynamic effect of the real to that of the ideal engine, showing the degree of approximation of the machine as operated to its ideal representative—the perfect engine, working in the stated cycle. This is a standard employed by Rankine and by Clausius.

For example, comparing the efficiency of the best modern steam-engine employing saturated steam, about 0·20, with the Rankine cycle, which is that ideal cycle which constitutes the closest approximation to its method of steam distribution, the ideal case giving an absolute efficiency, 0·25, it is found to have, measured by this latter standard, a relative efficiency of 80 per cent.; while, compared with the Carnot cycle, the figure becomes about 70 per cent.

Absolute and Relative Efficiencies must thus be explicitly distinguished, and it would seem desirable that all other so-called efficiencies than the first of this series should be denoted by the latter term. The efficiency relative to the Carnot, or to the representative Rankine, or other ideal thermodynamic cycle, if properly defined, often proves a valuable datum in comparing the actual with the ideal performance of engines for the purpose of ascertaining how closely

the performance of the engine, under test or in regular use, approximates the perfect thermodynamic action of the same machine, all its extra thermodynamic wastes being extinguished. The degree of this approximation measures the range and the limit of possible further improvement.

This standard of efficiency thus is seen to have its own special purpose and use. *The absolute efficiency* of any engine is a measure of the proportion in which thermal energy supplied is converted into work, and permits the comparison of various ideal or real available cycles. *The relative efficiency* measures the degree in which the actual performance in the chosen cycle approximates the purely thermodynamic ideal maximum for that cycle; the difference between the real and the ideal indicating the limiting range of possible further improvement and the degree of imperfection of the machine, as such.

Each of these several efficiencies measures a valuable datum, and, in fact, no investigation is complete in which a determination is not made of each: of the absolute efficiency, as measuring the proportion of work obtained from the supply of energy delivered to the engine; of the relative efficiency, the Carnot cycle taken as a standard, as measuring the approximation to a most perfect ideal heat-engine; and of the relative efficiency of the representative steam distribution, as the Rankine or other, as given by the valve-motion employed, and assuming a non-conducting cylinder —as measuring the approximation to perfection in the adopted cycle. Each has its use, and neither can be thrown out as superfluous.

The absolute standard, Joule's equivalent of thermodynamic conversion, is the limit of perfect transformation; the Carnot cycle is the gauge of limiting thermodynamic transformation in the most perfect possible heat-engine cycle; the type and representative cycles of Rankine and Clausius gauge the limits of perfection of the classes of engine which, by their construction, must work in one or another of those particular kinematic and physical cycles.

It is now proposed to study, in some detail, each of these now generally accepted typical cycles, and the several

efficiencies of these cycles, taken as standards with which to compare the real engine.

The Carnot Cycle, representing, as it does, the extreme limit of possible economy in the operation of the heat-engine of whatever kind, and having the same value for similar ranges of temperature, irrespective of the nature of the working fluid, furnishes a standard which was shown by Carnot himself to be that with which all actual cycles and the performances of all real engines should be compared, to ascertain what is the degree of their perfection or their imperfection.* Improvements of the steam-engine, from the earliest days of the modern Watt engine to the present time, have had for their purpose and as their result the widening of the range of adiabatic expansion, and the restriction of extra-thermodynamic wastes. This means the closer approximation of the cycle and the physical conditions affecting the operation of the machine to those ideal conditions pointed out by the great "founder of thermodynamics," thus bringing the final efficiency of the engine to coincide as closely as practicable with these maxima of the Carnot cycle of similar temperature-range.

The writer has been interesting himself in the computation of these ideal maxima, and has, in the earliest of the succeeding paragraphs, assumed those limits of temperature which were primarily taken by Rankine for his computations of other cases; the purpose being to secure a standard of comparison that should complement the earlier work. Modern steam-engines, by attaining a better vacuum and lower temperature-limit on the one hand, and by the employment of high-pressure steam, and by thus gaining a correspondingly higher limit at the other end of the temperature-range, actually attain these ideal figures and a still higher ideal standard. The latter are discussed later.

The Steam-Engine Working in the Carnot Cycle has, obviously, the same efficiency as any other heat-engine operating in the same cycle within the same temperature-range.

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* Carnot's "Reflections on the Motive-Power of Heat," Thurston's translation, p. 68. New York: J. Wiley & Sons.

The value of this efficiency is always $(T_1 - T_2) \div T_1$, and the figures given in the tables herewith are the same for all working fluids when the values of T_1 and T_2 are the same. In the computations, the results of which are here tabulated, it is assumed that the terminal pressure, p_2, and the back pressure, p_3, are identical, as prescribed by Carnot, and equal, respectively, in the cases paralleling the condensing and the non-condensing engine of the common type of cycle to 4 and 18 pounds per square inch, absolute. Pressures are taken from 300 pounds, absolute, downward. The steam is assumed to be initially dry and saturated. Values are computed for the ratio of expansion r, the mean effective pressure p_e, the efficiency E, the B.T.U. expended per horse-power per hour, and the weight of steam and of fuel demanded per horse-power per hour, each pound of fuel being assumed to supply 10,000 B.T.U. to the steam. The volume traversed by the piston per minute per horse-power is also computed and tabulated. These "ideal efficiencies" and data represent those limits which may be approached by the "real engine," but never actually attained. It is probable, judging from experience already had, that they may be taken as representing about one-half better work than can be expected in even the best practice of the best builders, the same limits of pressure and temperature being assumed.

The methods adopted in these computations are those original with Rankine, and similar to those applied by him to his special cases of the non-conducting cylinder and the ideal jacketed engine.* The following are the symbols and formulæ:

Carnot Cycle.

p_1 = initial pressure in pounds per square foot, absolute.
p_2 = pressure at the end of expansion.
  = back pressure. Expressed in pounds per square foot, absolute.

* "Steam Engine," Chap. IV, p. 104, *et seq.* Thurston's "Manual," Chap. V, Vol. I.

v_1 = initial volume.
= volume in cubic feet of 1 pound of dry and saturated steam at initial pressure.
[Take from steam-tables.]

v_2 = volume in cubic feet at the end of expansion =

$$\frac{1}{\frac{d\,p_2}{d\,T_2}}\left[J\,log._e\,\frac{T_1}{T_2} + v_1\,\frac{d\,p_1}{d\,T_1}\right].$$

$$= v_1\left(\frac{p_1}{p_2}\right)^{\cdot 881};\ \text{where}\ \cdot 881 = \frac{1}{1\cdot 135},\ \text{nearly.}$$

T_1 = absolute temperature in degrees F., corresponding to p_1.
[Add 461° to the temperature given in steam-tables.]

T_2 = absolute temperature in degrees F., corresponding to p_2.

L_1 = latent heat of evaporation, corresponding to p_1.
[Take from steam-tables.]

r = ratio of expansion.

$$= \frac{v_2}{v_1}.$$

H_1 = heat expended per pound of steam, expressed in foot-pounds.
$= J\,L_1$.

J = 778.

$$\text{Efficiency} = \frac{T_1 - T_2}{T_1}$$

U = net work done per pound of steam, expressed in foot-pounds.
$= H_1 \times$ Efficiency.

$$\text{M.E.P.}' = \frac{U}{v_2}\ \text{in pounds per square foot.}$$

$$\text{M.E.P.}'' = \frac{\text{M.E.P.}'}{144}\ \text{in pounds per square inch.}$$

A = B.T.U. per I.H.P per hour.

$$= \frac{2545}{\text{Efficiency}}.$$

B = pounds of steam per I.H.P. per hour for efficiency unity.

$$= \frac{1980000}{H_1}.$$

C = pounds of steam per I.H.P. per hour for actual efficiency.

$$= \frac{B}{\text{Efficiency}}.$$

W = equivalent "water-rate" from and at 212° F.

$$= \frac{A}{966{\cdot}069}.$$

F = pounds of fuel per I.H.P. per hour, at 10,000 B.T.U per pound, net.

$$= \frac{A}{10000}.$$

D = piston displacement per I.H.P. per hour.

$= C\,v_2$ cubic feet.

D' = piston displacement per I.H.P. per minute.

$$= \frac{D}{60}.$$

The process of determination of the values of work performed per unit weight of steam, or weight of steam per horse-power per hour, of the work per stroke of engine, of the mean pressures, and of the efficiencies and the weights of steam and of fuel, and the quantity of heat required in B.T.U. to perform the work computed, are, in brief, as follows:

The unit weight, in this case 1 pound of water, enters the steam cylinder at initial maximum temperature and pressure and in the liquid state. It expands into steam at constant pressure and temperature, receiving from the source of heat its latent heat of vaporization, and it presently becomes one unit-weight of steam in the dry and saturated state. At this point the heat supply ceases, and adiabatic expansion commences, converting stored heat energy into

work until the lower limit of temperature and pressure is reached, and the maximum volume of the cycle is attained. The piston is next driven back, compressing the fluid, gradually and isothermally, into smaller and smaller volume, until, at such point as is indicated for the cycle, compression becomes adiabatic, and both pressure and temperature commence rising, the line finally terminating at the point at which the cycle was begun. The fluid is now once more a mass of water, and in precisely the same physical condition as to pressure, volume and temperature as at the start. The thermodynamic as well as the kinematic cycle is complete.

During this process it is evident that, taking the cycle as a whole, neither gain nor loss of sensible heat has occurred, and all work performed must have been done by conversion of latent heat of vaporization from the thermal to the dynamic form of energy. Also, since all heat received is absorbed at the maximum temperature, and all rejected is discharged at the minimum temperature, this is a Carnot steam-engine cycle, and its efficiency must be $(T_1 - T_2) / T_1$, as in every Carnot cycle, whatever the nature of the working fluid and whatever the temperature and pressure limits. This may be readily shown, also, by detailed computations of the quantities of heat and of work, step by step, in the cycle.

In illustration of the quantities obtained in this form of the "ideal case," let it be assumed that we desire to ascertain the degree to which heat-conversion may be carried in such a cycle in a case corresponding to that of the common non-condensing engine, taking initial pressures at intervals up to 300 pounds per square inch, absolute, and a common back-pressure at 18 pounds, for the type representing the non-condensing and 4 pounds for the condensing engine. It is required to find the pressures, volumes, temperatures, work performed and efficiencies. The steam-tables are relied upon for the measures of temperatures, pressures and latent heat. The accompanying figure presents, in graphical form, the resultant figures.

Computations being made for the case in which the Carnot

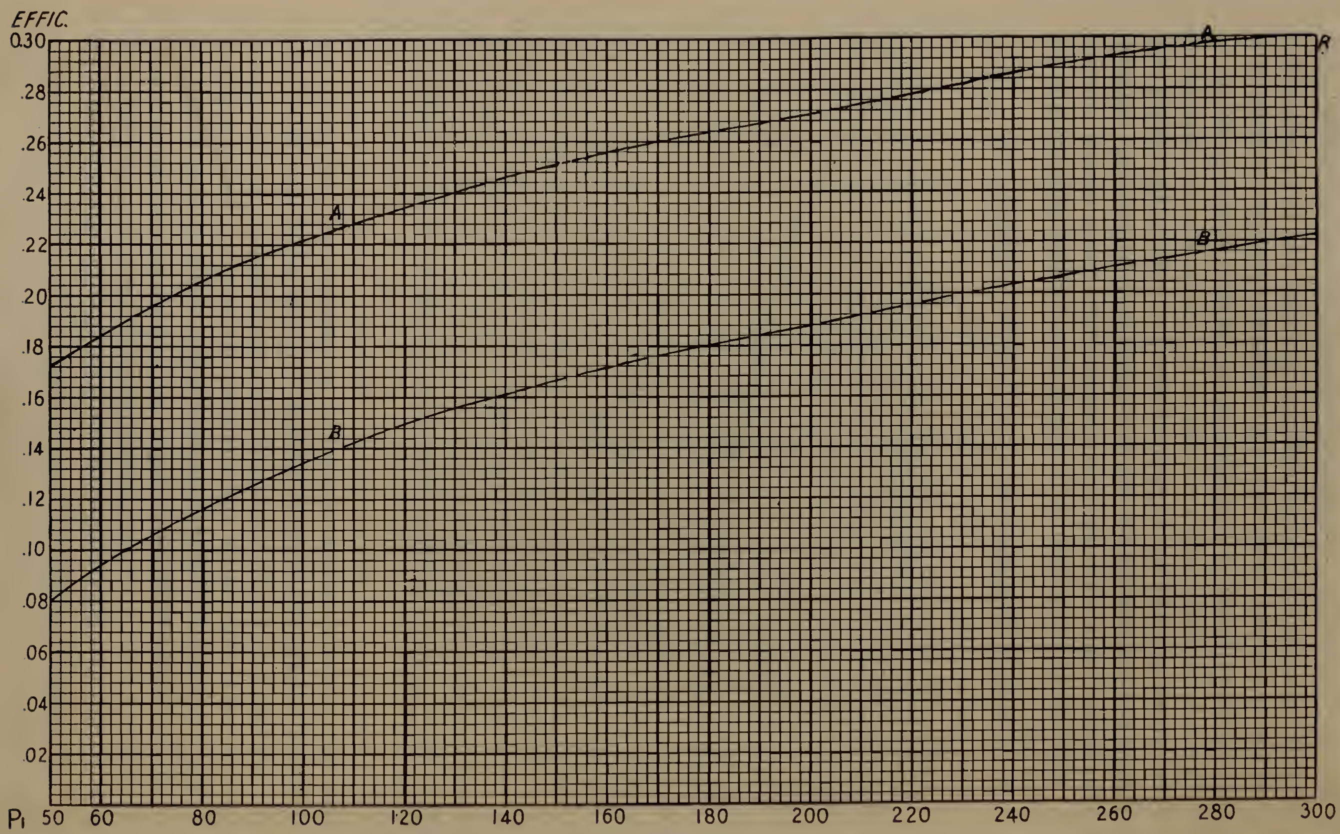

FIG. 1.—Carnot Cycle. For condensing engine, $p_2 = 4$; non-condensing, $p_2 = 18$.

cycle is given a range suitable for comparison with the best of our modern engine-cycles, we obtain figures which are grouped in the tables later presented, with the results of similar computations for the other standard cycles adopted in these discussions. The graphical representation of these results, and the efficiencies attainable under such conditions, by the cycle of the so-called perfect engine, are shown in the diagram, *Figs. 1* and *2*, where, as is seen, curves are constructed for the range of pressure already taken, to 300

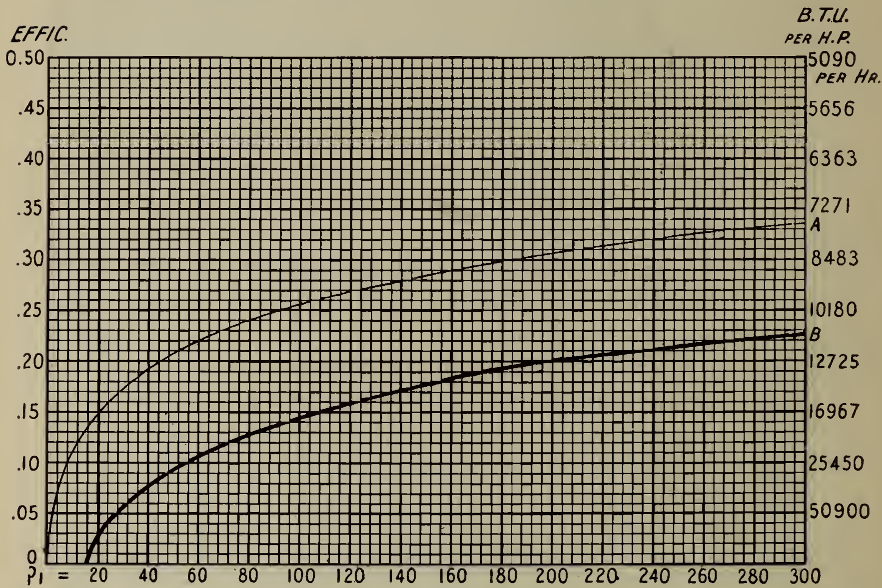

FIG. 2.—Carnot Cycle.

For condensing engine, $p_2 = 2$; non-condensing, $p_2 = 16$.

pounds initial pressure, and for back-pressures of 18 and 16 and of 4 and 2 pounds, respectively, for the non-condensing and for the condensing engine cycle, which ranges constitute the limits for the ideal cycles selected. In the last set of data tabulated in this series, it is assumed that the fuel employed is of such quality that it is capable of supplying, by the combustion of unit weight, all the heat required for the evaporation of 12 units of weight of the fluid from and at the temperature of the steam produced.

The Rankine Cycles, taken as Standards, permit the computation of the quantity of heat, steam, and fuel of a stated quality, which would be demanded by the ideal engine, by a steam-engine working in such a cycle and free from extra-thermodynamic wastes, such as invariably reduce enormously the efficiency of the real engine. Comparing the real engine with its ideal representative, it becomes possible to determine the nature and extent of its wastes and the method to be pursued in the endeavor to improve the machine as a thermodynamic engine. There are usually studied two cycles, originally discussed by Rankine—the adiabatic Rankine cycle and the Rankine cycle for steam retained dry and saturated.

The Rankine Adiabatic Cycle is the ideal toward which the common Corliss engine approximates most closely, a cycle which is characterized by variation from the Carnot by incomplete adiabatic expansion and by absence of clearance and compression. The steam enters the engine at boiler pressure, is expanded adiabatically—the cylinder being assumed to be non-conducting—is exhausted from a terminal pressure exceeding the back-pressure, and is completely rejected from the system at a constant back-pressure. The heat supplied is that required to raise the temperature of the feed-water from that of supply—as a maximum from that of the rejected fluid—and to vaporize it at the boiler pressure and temperature. In this respect, the case differs from that of the Carnot cycle, which demands only the supply of the latent heat of vaporization. The rigidly thermodynamic process here illustrated is the following:

Steam is produced by raising the temperature of a mass of feed-water, constituting one charge and acting as the vehicle of the heat acting in a single cycle of the engine, to that of the steam at boiler-pressure, and vaporizing it at that temperature and pressure. Unity of weight being assumed as a single charge, this amount of steam is introduced at boiler-pressure; adiabatic expansion occurs from initial to terminal pressure; reduction of pressure takes place at constant volume until back-pressure is reached;

reduction of volume then occurs at constant pressure until, the quality constantly changing, the fluid becomes entirely liquid—and the cycle is complete.

The Steam-Engine Working in the Rankine Adiabatic Cycle experiences not only the loss of thermodynamically rejected heat, as does the Carnot the minimum possible loss, but also loses efficiency by its incomplete expansion and by its omission of the adiabatic and complete compression of the "dynamic feed-water heater." Thus, while the Carnot cycle serves to determine the total of all wastes, when the work of the actual engine is compared with it, that of Rankine serves the especial purpose of exhibiting the wastes of the real steam-engine having such a steam distribution as may be taken to be fairly represented, in the ideal case, by this cycle. It shows what gains remain to be effected in such a type of engine by extinction of wastes due to the non-adiabatic character of the operation.

In the cycle computed—and of which the figures are given in the appended tables—it is assumed that the terminal pressures are 7 pounds per square inch absolute, and 21 pounds, respectively, for the condensing and the non-condensing engines. The back-pressures are taken at 2 and at 16 pounds.

The comparison of the two preceding ideal cycles shows what may be gained by change of the design of the engine and of its valve gear in such manner as to reproduce the as yet unattained cycle of the "perfect engine of Carnot." The relative efficiency of the real engine-cycle and the ideal of Rankine measures imperfections of the extra-thermodynamic conditions of operation of the engine; the relative efficiency of the Rankine and the Carnot ideal cycles measures the defects of the thermodynamic action of the machine.

The Method of Computation is briefly as indicated in the following summary:*

Rankine's Adiabatic Engine-Cycle.

v_1 = volume in cubic feet at point of cut-off.

* Thurston's "Manual of the Steam Engine," Vol. I, § 116.

= initial volume = volume of 1 pound of dry and saturated steam at the pressure chosen.

[Take from steam-tables.]

v_2 = volume at end of expansion.

= $v_1 r$.

r = ratio of expansion.

[In no case expand below back-pressure.]

p_1 = initial pressure in pounds per square foot, absolute.

p_2 = pressure at the end of expansion, expressed in pounds per square foot, absolute.

$$= p_1 \left(\frac{v_1}{v_2}\right)^{1\cdot135}$$

p_3 = back-pressure in pounds per square foot, absolute.

= 2 × 144 = 288 pounds per square foot for condensing engine.

= 16 × 144 = 2,304 pounds per square foot for non-condensing engine.

J = 778· foot-pounds per degree F.

T_1 = absolute temperature in degrees F., corresponding to p_1.

[Take temperature from steam-tables and add 461°.]

T_2 = absolute temperature in degrees F., corresponding to p_2.

T_4 = absolute temperature in degrees F. of feed-water.

= 104 + 461 = 565° F., for condensing engine.

= 210 + 461 = 671° F., for non-condensing engine.

λ_1 = total heat of evaporation, corresponding to p_1, in B.T.U.

[From steam-tables.]

q_4 = heat in feed-water at T_4, in B.T.U.

= $T_4 - (461 + 32)$.

U = net work done per pound of steam (in foot-pounds).

$$= J \left[T_1 - T_2 \left(1 + \log_e \frac{T_1}{T_2}\right)\right] + \frac{T_1 - T_2}{T_1} H' + v_2 (p_2 - p_3).$$

L_1 = latent heat of evaporation, corresponding to p_1, in B.T.U.

[From steam-tables.]

H' = same in foot-pounds = $J\,L_1$.

H_1 = heat expended per pound of steam, in foot-pounds.
$= J\,(\lambda_1 - q_4)$.

$$\text{Efficiency} = \frac{U}{H_1}.$$

$$\text{M.E.P.}' = \frac{U}{r\,v_1} = \frac{U}{v_2} \text{ in pounds per square foot.}$$

$$\text{M.E.P.}'' = \frac{\text{M.E.P.}'}{144} \text{ in pounds per square inch.}$$

A = B.T.U. per I.H.P. per hour.

$$= \frac{2545}{\text{Efficiency}}.$$

B = pounds of steam per I.H.P. per hour for efficiency unity.

$$= \frac{1980000}{H_1}.$$

C = pounds of steam per I.H.P. per hour for actual efficiency.

$$= \frac{B}{\text{Efficiency}}.$$

W = equivalent "water-rate" from and at 212° F.

$$= \frac{A}{966{\cdot}069}.$$

F = fuel per I.H.P. per hour.

$$= \frac{A}{10000}.$$

D = piston displacement per I.H.P. per hour.
$= C\,v_2$ cubic feet.

D' = piston displacement per I.H.P. per minute.

$$= \frac{D}{60}.$$

The Rankine Cycle for Continuously Dry Steam, the cycle of the ideal jacketed engine, is defined as that in which, by the introduction of heat during the process of expansion, the con-

densation due the transformation of heat into work in the expansion period—discovered by Rankine and Clausius, independently and almost simultaneously—is prevented, and the working charge is thus kept dry and saturated throughout the forward stroke of the piston. It differs from the adiabatic cycle in the fact that heat is thus continuously passed into the cylinder, and into the working charge during the whole period of expansion, and thus the quantity of heat demanded per stroke is increased, the work performed is somewhat enhanced, while the efficiency is diminished in consequence of the fact that Carnot's principle is not adhered to, and heat is not all supplied at the higher limit of temperature, as is the case in the preceding form of cycle.

In this cycle, the steam is assumed to enter the engine dry and saturated, to expand with absorption of heat from the jacket, in precisely that quantity required to retain it in the dry and saturated state, and to describe the same lines on the diagram, during exhaust, as in the case of the adiabatic cycle of Rankine. The quantity of steam demanded in a cycle is the sum of that passing through the engine and that condensed at boiler-pressure in the jacket to supply the heat required to keep the charge dry. The quantity of heat supplied is that demanded for the production of both quantities of steam—the first from the temperature of the feed-water, the second from that of boiler-steam.

The Steam-Engine Working in the Second Rankine Cycle is assumed to at least approximate the ideal cycle. As stated by the author of this method of discussion, the absorption of heat by the steam is exceedingly rapid when moist, very slow when dry; and it may thus, as he states, be assumed that the condition of the steam in the engine is substantially that of the ideal case. Actually, however, as shown by innumerable engine-trials, even the most perfect jacketing does not produce precisely the condition assumed in the ideal case. Extra-thermodynamic wastes, usually, in good practice, not far from one-half the amount of those of the real engine, unjacketed, are observed. It is the difference produced by the remanent wastes, externally and inter-

nally, that measures the imperfection of the machine as a thermodynamic apparatus.

The ratio of the computed efficiency of the ideal engine to the observed and measured efficiency of the real engine constitutes a gauge of the excellence of the design and of its construction, such as makes this cycle a valuable standard for this special purpose; exactly as the Rankine adiabatic and the Carnot cycle each in its way serves as a special and useful standard. Here, as in the preceding case, the relative efficiency of the real in comparison with the Carnot cycle measures the total imperfection of the machine as a heat-engine; while the relative efficiency of this ideal cycle, as compared with the Carnot, gives a measure of the imperfection of the thermodynamic cycle adopted.

[*To be concluded.*]

CHEMICAL SECTION.

Stated Meeting, held November 17, 1896.

DR. H. F. KELLER, President, in the Chair.

A NEW HIGH-TEMPERATURE FURNACE.

BY H. L. GANTT, A.B., M.E.

Until recently the difficulty of obtaining and controlling extremely high temperatures has kept us to a large measure in ignorance of the uses to which they may be applied. Within the last few years, however, the electrical furnace has thrown a flood of light on this subject, and we to-day realize that high as the temperature of the Siemens steel melting furnace and the blast furnace seems to be, temperatures far higher are destined to be extensively used in the arts at an early date.

Already the electrical furnace has been brought largely into play in the manufacture of aluminum and calcium carbide, and while we realize that electricity is a most efficient and convenient method of obtaining the necessary high temperatures, we must not lose sight of the fact that it is an exceedingly expensive one, and we feel bound to inquire

if even in the Siemens furnace we have exhausted all the possibilities of producing high temperatures by means of combustion. It is the object of this paper to inquire into this subject and to find out the possibilities that may lie in the field of a furnace producing a temperature from 1,000° to 2,000° higher than that of the Siemens furnace.

The actions carried on in the electrical furnace, and, in fact, all the actions we propose to study, are of a reducing nature, hence it is necessary that we have an excess of carbon present in our furnace, and, fortunately for our investigation, the highest temperatures obtainable by combustion can be gotten by burning carbon with hot air. Our furnace must then be on the order of a blast furnace, which, while producing a temperature amply high for the purpose of reducing iron from its ore, does not by any means attain the maximum temperature possible by the combustion of carbon.

To try to form some idea of what temperature we may be able to get, we had better consider a coke-fired crucible steel-melting furnace, blown with a cold blast. In such a furnace very soft steel can be melted and made perfectly fluid in about four hours, and that, too, in a pot, the walls of which have but poor heat-conducting power. As the temperature of such steel is about 3,000° F., it is safe to say that the fire reaches a temperature at least 1,000° higher, or about 4,000°.

It will be shown later that we can readily heat our air blast to a temperature of 3,000° F., and we have to ask—what temperature can be obtained with such a blast? If a cold blast will give a temperature of 4,000° F., a blast heated 3,000° ought to add just that much to the temperature of the fire, which would then be 7,000° F. We should not, of course, expect to realize all the benefit from the heat in the blast, but we may safely assume that we shall get two-thirds of it, and that our fire will reach the temperature of 6,000° F.

With regard to the possibility of obtaining a temperature of 6,000° F., there will undoubtedly be a difference of opinion; but so far, all our calculations have been based upon the assumption that the combustion takes place under a comparatively low pressure, but we may build our furnace

in such a manner as to admit of our maintaining in it a pressure of one or more atmospheres, in which case the temperatures will be much higher, and in the furnace about to be described, the writer believes there will be no difficulty in obtaining a temperature of at least 6,000° F.

The furnace in question resembles the blast furnace, inasmuch as it is a shaft furnace fired with coke and blown through tuyeres, but differs from the blast furnace in the use of regenerators instead of hot-blast stoves. At the same time the regenerators are something more than is ordinarily included under that term, for in these chambers we complete the combustion of the blast furnace gases, in which respect they resemble somewhat hot-blast stoves. This, however, is as far as the resemblance goes, for the air used to complete this combustion in the regenerators is hot air, while in hot-blast stoves it is cold.

To obtain the conditions above enumerated, we build a Siemens regenerative furnace, which has for the combustion chamber a shaft to hold the fuel and charge and one set of regenerators. If we now connect these regenerators with each other by means of one or more passages near the top, the hot air will be divided into two portions, one of which will pass through the furnace, promoting combustion therein, and the other will pass directly to the outgoing regenerator and complete in there the combustion of the carbonic oxide in the gas to carbonic acid.

In the cuts herewith, *A* represents the combustion chamber, or furnace proper; *G* and *G′* the tuyeres, or flues through which the air enters and the products of combustion leave the furnace; *C* and *C′* are the regenerator chambers in which the secondary combustion takes place, the hot air for which is supplied through the passage *E*.

D and *D′* are simply additional regenerators, connected respectively with *C* and *C′*, long regenerators of small cross-section being considered more efficient than shorter ones of larger sectional area.

K is a four-way reversing valve, through which the blast enters the furnace, and the products of combustion escape to the stack. The furnace proper is provided with three


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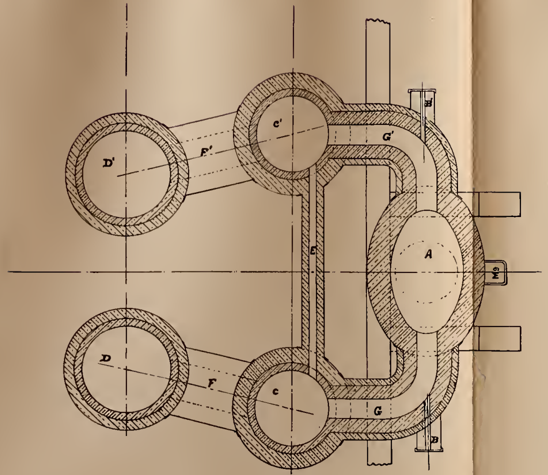

FIG. 2.—Section through *A B*.

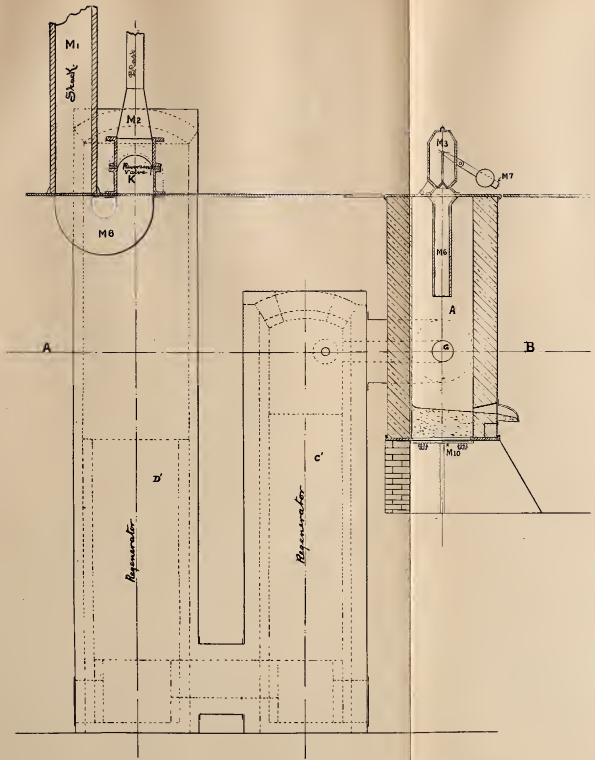

FIG. 1.

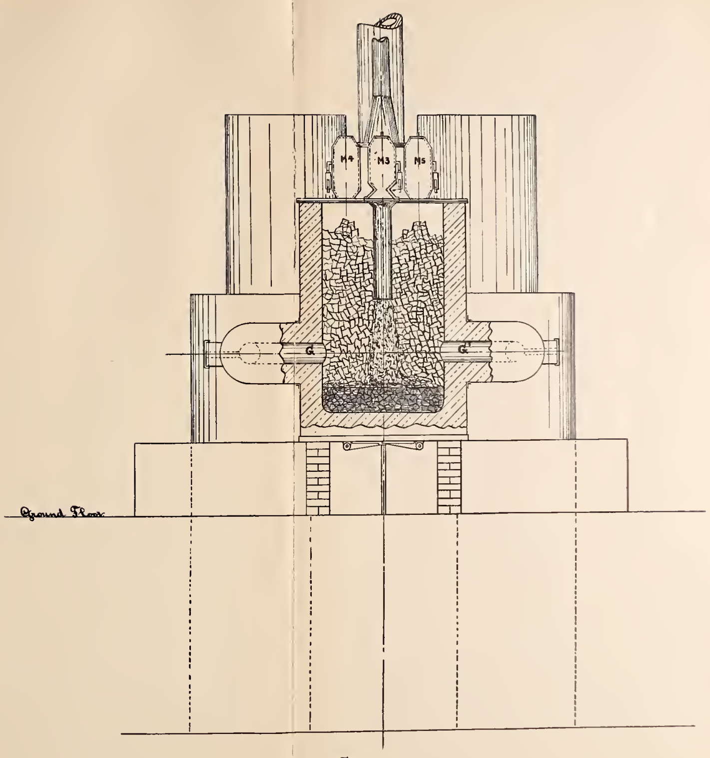

FIG. 3.

H. L. GANTT'S HIGH-TEMPERATURE FURNACE.

hoppers, the center one for the material to be reduced and the other two for coke, which by this means is made to surround the charge entirely and protect it from any oxidizing action.

The temperature which we can obtain in this furnace evidently depends upon the temperature of our blast, which, in turn, depends upon that of the regenerators C and C'.

In order to consider what temperatures we may expect to get in these chambers, let us suppose the furnace to have a fire in the chamber A, but to be otherwise quite cool. If a blast be blown through K, D, F, C and G, we know we can in a short while get a temperature in A of from 3,500° to 4,000° F. The products of combustion escaping into C', at the above temperature, will be further burned by the air passing through E, and it is safe to say that the chamber C' may be heated to the same temperature as the furnace. If, now, the direction of the blast be reversed, the temperature of the air going into A and through E will certainly be 2,000° F., and our furnace temperature will rise to perhaps 5,000° F., and the products of combustion, containing a large percentage of carbonic oxide, will reach the chamber C at a temperature but little lower. These, mingling with air at 2,000° F., will undergo further combustion, and, if they do not increase in temperature, will at least not cool much, and we may certainly expect to get the chamber C up to between 4,000° and 4,500° F. Upon reversing, we shall be able to get the air to a temperature above 3,000° F., which was the temperature we considered necessary to give us 6,000° F. in the furnace. As our furnace approaches 6,000° F. in temperature, our regenerators will probably approach 5,000° F., and there seems to be but little doubt that we shall be able to get a temperature as high as we desire, or at least as high as we can find materials to resist.

Having seen what temperatures we can probably obtain in a coke-fired furnace of the proper form, let us try to find out exactly what goes on in an electric furnace and make a comparison of the two sets of conditions.

The formation of calcium carbide in the electrical furnace by means of lime and coke was discovered by Dr. Borchers

about ten years ago. He seems to have investigated the subject quite carefully, and proved to his satisfaction what has since been demonstrated, that the action is not due to electricity, as such, but to the heat produced by it. A short account of his experiments is given in the *Engineering and Mining Journal* of October 14, 1895. More recently this method of manufacture has been put upon a commercial scale by Mr. T. L. Willson, and calcium carbide is said to be manufactured now in large quantities at Niagara Falls.

With regard to the temperature in the electrical furnace, M. Henri Moissan, *Comptes Rendus*, July–December, 1892, Vol. CXV, p. 1,031, tells us that at 3,000° C. (5,432° F.) carbon reduces oxide of calcium, and that the metal is liberated in abundance and unites with the carbon of the electrodes to form calcium carbide.

The difficulty of measuring or even estimating the extremely high temperatures of the electrical furnace is very great; but it is safe to say that the formation of calcium carbide being an endothermic reaction, the temperature of the furnace does not rise much above the point at which it goes on freely, for any heat over and above the amount necessary to maintain this temperature would undoubtedly go to promote chemical action rather than to cause a further increase of temperature, which is probably not very much above 5,5co° F. These conditions are so nearly identical with those which our coke furnace promises, namely, a temperature of 6,000 ° F. and a strongly reducing action, that it would seem that any reaction produced in one furnace would occur in the other.

Further, Mr. Walton Clark, General Superintendent of the United Gas Improvement Company, of Philadelphia, is my authority for the statement that there is produced in the blast furnace a substance which, with the addition of water, will give off acetylene gas.

The railroad leading to Chestnut Hill, a suburb of Philadelphia, where Mr. Clark lives, is ballasted with blast furnace slag, and he has often perceived the odor of acetylene in passing over a piece of newly ballasted road after a rain. Knowing lime to be a constituent of the blast furnace

charge, it is certainly most probable that the carbide in the slag giving off acetylene when dampened is that of calcium. If now we grind together a mixture of lime and coke with a little tar for a bond to prevent waste of the ground-up material, and having dried it, charge it in small lumps through the center hopper of our furnace, we shall have conditions far more favorable for the formation of a carbide than can possibly occur in the blast furnace, and almost identical with those occurring in the electrical furnace.

Again, our furnace offers the most favorable conditions that have yet been contrived for the study of that most interesting of problems, the fixation of atmospheric nitrogen and the manufacture of cyanides. The manufacture of cyanides, and especially potassium cyanide, in small quantities in the blast furnace, has been long known, but the conditions most favorable have not been determined. The amount of work being done on the subject now, which is best illustrated by the number of British patents dealing with cyanides, ferrocyanides and sulphocyanides, published during the past ten years, a table of which is given below, indicates an early solution of the problem. The table is as follows:

1886.	*1887.*	*1888.*	*1889.*	*1890.*	*1891.*	*1892.*	*1893.*	*1894.*	*1895.*
4	5	2	4	4	5	7	12	15	33

At a meeting of the Society of Chemical Industry, January 8, 1896, Mr. James T. Conroy, B.Sc., Ph.D., presented a paper, entitled, "Some Experiments Relating to the Manufacture of Cyanides," which is published in the *Journal of the Society of Chemical Industry*, January 31, 1896, and reviews the work that has been done in this line. I give the following extracts from his paper:

"Professor Clark, in 1837, found the efflorescence occurring near the boshes of the Clyde blast furnaces, worked with hot blast, to consist chiefly of potassium cyanide. A similar phenomenon was found to occur in the Hartz, where the hot blast was used; and in 1843, Redtenbacher found it near the light-hole in the furnaces at Marianzoll, in Styria, where it has been produced in marketable quantities. In 1845, Bunsen and Playfair investigated the subject, and

found the zone of formation was just above the tuyeres. To estimate the quantity formed, they drilled a hole in this portion of the furnace and conducted the issuing gas into water. The analysis of the gas gave:

N	58·05
CO	37·43
H	3·18
CN	1·34

"As a result of his work, Bunsen proposed a special blast furnace for the production of cyanides, in which coke and potash were arranged in alternate layers and heated with a strong blast."

It does not appear, however, that such a furnace was ever built.

Continuing our extracts:

"Riechen then investigated the subject and found, under conditions in which only atmospheric nitrogen was present, that cyanides were formed, and he further showed that the temperature must be sufficiently high to produce metallic potassium and that the nitrogen gas should be previously heated.

"His experiments were confirmed by Delbruk.

"These facts having now been firmly established, many attempts have been made to found a working process upon them, and numberless patents, all very similar to each other, have been taken out, but none have proved commercially successful.

"The essential feature is conducting nitrogen (N), or, in the later processes, ammonia (NH_3), over a heated mixture of coke and potash, but the temperature of the formation of the cyanides is in all cases extremely high, in fact, so high as to kill the process, especially when ammonia is used, since this gas decomposes rapidly at the temperature employed."

As a practical confirmation of the above, the most recent patents on the subject specify an intimate mixture of potash (K_2CO_3) and carbon to be subjected to a high heat in the presence of ammonia or nitrogen, and further state that if nitrogen be used the temperature must be very high.

If through the center hopper of our furnace we drop a mixture of coke and potash, which have been thoroughly ground together with a little tar and then dried and broken into lumps, we can obtain these conditions almost perfectly, and the experiment of making potassium cyanide in this manner seems to be worth making.

The next question is—how are we to build a furnace that will withstand such temperatures? In order to resist the fluxing action of lime, the furnace must be lined with a basic material, and, luckily, the most refractory substance available is magnesite, which is basic. What temperature magnesite will stand when subjected to no fluxing action, we do not know, but we do know that it is much more refractory than lime. Again, in the hottest portion of the furnace the exposed surfaces of the magnesite brick will, undoubtedly, become covered with a coat of magnesium carbide, which will probably protect them somewhat. All things considered, it seems quite possible to get a lining to resist the temperature needed.

There are numerous other uses to which this furnace may be put, which are much less problematical than those just discussed, but as they lie in an entirely different line, they are foreign to the subject of this paper.

DISCUSSION.

DR. JOS. W. RICHARDS (Correspondence):—Mr. Gantt's proposed furnace is based on sound metallurgical principles. He would not, however, theoretically attain to the temperatures mentioned in his paper. The obtaining of refractory material to withstand temperatures between 2,000° and 3,000° C. is, furthermore, not so easy. Moissan has found in the electric furnace that at 2,300°–2,400° C. pure alumina melts to a limpid liquid; at 2,600°, magnesia becomes fluid; at 2,800°–3,000°, lime melts, especially in presence of carbon. The only remedy I can propose for this melting of the lining is a water-jacketed furnace, or, at least, water-jacketed around the zone of greatest heat, and then lined with magnesia. The rate of loss of heat would necessarily

be greater than with pure magnesia walls; but the melting would be checked within a certain distance of the water-jacket, and the lining thenceforth consist of chilled magnesia.

Regarding the theoretically attainable temperature—leaving conduction of heat out of the question, and considering merely the highest temperature momentarily attainable at the instant of combustion—I have made the following calculations:

Let the reaction be:

$$2C + O_2 = 2CO = + 57{,}280 \text{ cal.},$$

and the heat set free, calculated to 0° C., taken as 2,387 calories per kilo of carbon, based on Berthelot and Thomsen's best results. We must first calculate the heat of this combination at high temperatures (represented by t) in order to get the true quantity of heat developed in the furnace. This calculation is based on the principle of thermo-chemistry, that the heat of combustion at any temperature equals the heat of combustion at 0°, *plus* the heat capacity of the fuel and oxygen to that temperature, *minus* the heat capacity of the oxidized product from that temperature to 0°.

For these calculations we have the following data:

Heat in 1 kilo carbon at $t° = 0{\cdot}53\, t - 134{\cdot}6$ calories.

(For t over 1,000° C. calculated from Weber's results.)

Heat in 1 kilo oxygen at $t° = 0{\cdot}131875t + 0{\cdot}00005t^2$.

Heat in 1 kilo carbonic oxide $= 0{\cdot}1507t + 0{\cdot}000057t^2$.

(For t between 1,600° and 4,000° C.—Vielle and Berthelot.)

We therefore have:

Heat capacity of C_2 (24 kilos) $= 12{\cdot}72t - 3{,}230$ cal.
Heat capacity of O_2 (32 kilos) $= 4{\cdot}22t + 0{\cdot}0016t^2$ cal.
Heat capacity of $2CO$ (56 kilos) $= 8{\cdot}44t + 0{\cdot}0032t^2$ cal.

And, hence, for temperatures between 1,600° and 4,000° C.:

$$2C + O_2 = 2CO = 54{,}050 + 8{\cdot}5t - 0{\cdot}0016t^2 \text{ cal.}$$

However, since the temperature of the air used may vary, it will be more convenient to leave out of the above expression the heat capacity of the oxygen, and thus to obtain an expression for the heat generated at $t°$ by the combustion of carbon by cold air. If we further omit the heat capacity of 2CO, we will have the heat generated in the furnace, inclusive of the heat capacity of the product, down to 0° C. as a base. This expression is

$$2C + O_2 = 2CO = 54{,}050 + 12{\cdot}72t.$$

Having now an expression for the heat generated by the combustion with cold air, the next step is to calculate an expression for the heat capacity of the air used, in order that, if it be preheated, its sensible heat may be added to the heat generated by combustion, to obtain the total heat in the furnace.

The heat capacity of 1 kilo N $= 0{\cdot}1507t + {\cdot}000057t^2$.

$O_2 = 32$ kilos corresponds to $106\frac{2}{3}$ kilos of nitrogen.

$$\begin{array}{ll} \text{Heat capacity of } 106\tfrac{2}{3}\text{ N} & = 16{\cdot}075t + 0{\cdot}0061t^2. \\ \text{Heat capacity of } 32\ \text{O} & = 4{\cdot}22t + 0{\cdot}0016t^2. \\ \hline \text{Heat capacity of air needed} & = 20{\cdot}295t + 0{\cdot}0077t^2. \end{array}$$

The final step is to calculate an expression for the heat capacity of the products of the combustion. These are:

$$\begin{array}{ll} \text{Heat capacity of 2CO (56 kilos)} & = 8{\cdot}44t + 0{\cdot}0032t^2. \\ \text{Heat capacity of [N] } (106\tfrac{2}{3}\text{ kilos}) & = 16{\cdot}075t + 0{\cdot}0061t^2. \\ \hline \text{Heat capacity of products} & = 24{\cdot}515t + 0{\cdot}0093t^2. \end{array}$$

Gathering these expressions together, we have:

$$\begin{array}{ll} \text{Heat developed by the combustion} & = 54{,}050 + 12{\cdot}72t. \\ \text{Sensible heat of hot air} & = 20{\cdot}295t + 0{\cdot}0077t^2. \\ \hline \text{Sensible heat of products of comb'stion} & = 24{\cdot}515t + 0{\cdot}0093t^2. \end{array}$$

Proceeding from these expressions, and making the assumption that the products of combustion contain, as sensible heat, the sum of the sensible heat in the preheated

air and the heat generated by combustion, we have the following deductions:

I. Air for combustion, cold—

$$24{\cdot}515t + 0{\cdot}0093t^2 = 54{,}050 + 12{\cdot}72t.$$

from which

$$T = 1{,}860° \text{ C.}$$

This result is not very different from what we know can be obtained by charcoal and an air blast, by which platinum (melting-point, 1,775° C.) has been melted by Meyer; but it must be remembered that, in a shallow fire, carbon burns partly to CO_2, but that, in a furnace of any size, such can only be the case within a few inches of the blast nozzle, and that the body of the furnace probably approximates the temperature calculated above.

II. Air preheated to 730° C.

Heat in air $= 20{\cdot}295\,(730) + 0{\cdot}0077\,(730)^2$	$= 18{,}918$ cal.
Heat developed by combustion	$= 54{,}050 + 12{\cdot}72t.$
Total heat in furnace	$= 72{,}968 + 12{\cdot}72t.$

Whence

$$24{\cdot}515t + 0{\cdot}0093t^2 = 72{,}968 + 12{\cdot}75t.$$

and

$$T = 2{,}238° \text{ C.}$$

I have chosen this temperature of air, because it is about the average of the hot-blast for a furnace producing grey iron, and on such a furnace LeChatelier has measured the temperature at the level of the tuyeres as 1,930° C. Since the absorption of heat by slag and iron, and by the expansion of the blast, were not considered in the calculation which gave 2,238°, the agreement may be considered fairly satisfactory.

III. Air preheated to 1,000°.

$$T = 2{,}400° \text{ C.}$$

IV. Air preheated to 1,500°.

$$T = 2{,}735° \text{ C.}$$

V. Air preheated to 2,000°.

$$T = 3{,}095^\circ \text{ C.}$$

VI. Air preheated to 2,500°.

$$T = 3{,}470^\circ \text{ C.}$$

VII. Air preheated to T°.

$$T = 9{,}000^\circ \text{ C.}$$

The last result gives the theoretical temperature attainable by Mr. Gantt's process, pushed to its extreme limit, *i. e.*, with the incoming air preheated to the maximum temperature attainable in the furnace. Of course, it has only a theoretic interest, as showing the imaginary maximum. Practically, result V (air at 2,000° — furnace at 3,000°) gives what, I think, will be the maximum temperature which it will be possible to attain in an actual test, with the use of materials available, and with the minimum of burden on the fuel.

NOTES AND COMMENTS.*

A PROCESS FOR ELECTROLYTIC DESILVERING ARGENTIFEROUS LEAD.

D. Tommasi, in the *Engineering and Mining Journal*, describes the following mode of procedure:

The principle on which this procedure is founded consists in electrolyzing a lead solution, which not merely possesses an extremely weak electric resistance, but does not give rise to lead peroxide (PbO_2), and, in taking the argentiferous alloy itself as anode and cathode, a metallic disc which cannot be attacked by the bath.

Under the action of the current the lead of the anodes enters into solution, and is transferred, in the state of spongy crystals, upon the disc which serves as cathode, while all the silver contained in the lead, being insoluble in the bath, is deposited at the bottom of the vat in a perforated receiver destined for its collection.

The following is the course to be followed for the electrolytic extraction of silver from argentiferous lead:

We melt the lead and then cast it in moulds having the shape and the thickness which are intended for the anodes. This being done, we suspend

* From the Secretary's monthly reports.

each anode to one of the two metallic poles which are found placed about the upper part of the electrolyzer.

Each metal pole is fitted with an endless screw and with nuts. At the ends of these poles are fixed plugs intended to connect the anodes electrically among themselves, and to secure the whole to the positive pole of the dynamo.

The object of this arrangement is not merely to keep the electrodes at a determined distance from each other, but to approximate them if this distance becomes too great in consequence of the progressive wear of the anodes.

The disc which serves as cathode is placed between the two anodes, and communicates with the negative pole of the dynamo by means of a metal brush rubbing upon its axle.

The electrolyzer being fitted up, we pour in the bath (a solution of the double acetate of lead and sodium, or of lead and potassium), close the circuit, and cause the disc to revolve at the rate of one or two rotations per minute.

When the current is established, the lead begins to deposit upon the disc in the form of small, spongy crystals. When the deposit of lead has acquired a sufficient thickness, and it is thought suitable to remove it, the current is interrupted and the scrapers closed.

In consequence of their friction against the faces of the disc, the lead is detached and falls into sloping gutters, which bring it upon a sieve of metal cloth. The lead is drained, washed with distilled water and then submitted to a strong pressure.

The liquid which flows off is added to the washing-waters, and the whole evaporated down to 30° Baumé. When cold, this liquid is introduced into the electrolyzers by means of a pump. The compressed lead is heated on a crucible with 2 or 3 per cent. of charcoal in powder, and when melted it is cast in ingots.

When the anodes are dissolved, we may either replace them with fresh anodes, or merely withdraw the silver deposited at the bottom of the vat. In this latter case, we raise the disc by means of a windlass, then withdraw the perforated recipient placed at the bottom of the vat at the beginning of the operation; this contains all the silver left behind by the argentiferous lead of the anodes.

The silver, when collected, washed and dried, is melted in a crucible with sodium nitrate and a little borax, and is then cast into ingots.

METALLIC CARBIDES.

Among the many new fields of work opened up by the introduction of the electric furnace, according to *Nature*, is the preparation of difficultly-reducible metals undertaken with success by M. Moissan. These reductions being necessarily effected by the presence of carbon, the formation of definite metallic carbides of great stability soon became apparent, the properties of which came to be of such interest that their preparation was systematically attempted. Certain metals, such as gold, bismuth, lead and tin, do not

form carbides at the temperature of the electric furnace, neither do they dissolve any carbon. The metals of the platinum group dissolve carbon with facility and deposit the whole of it, on cooling, in the form of graphite, the metals being unchanged. Copper, silver and iron take up carbon in quantities, which, although small, are sufficient to cause marked changes in the physical properties of the metals; it is noteworthy that no definite crystalline compound could be obtained with iron. On the other hand, fused aluminum takes up carbon readily in the formation of the crystalline carbide, Al_4C_3, and the oxides of many other metals furnish similar crystalline compounds when heated in an electric furnace with an excess of carbon. The behavior of these substances with water furnishes the most convenient mode of classification. The carbides of molybdenum, tungsten, titanium, zirconium, the latter having two, and of chromium, also having two, do not decompose water at the ordinary temperature. Of these reacting with water, the carbides of lithian, calcium, strontium and barium furnish a pure acetylene; of aluminum and of beryllium, pure methane; of manganese, a mixture of equal volumes of hydrogen and lethane; while metals of the cerite group give crystalline carbides, all of which react with cold water, forming a complicated gaseous mixture containing hydrogen, acetylene, ethylene and methane. But the most complex reaction is that furnished by uranium carbide with water. In this case, in addition to the gaseous mixture containing methane, ethylene and hydrogen, liquid and solid hydrocarbons are produced in abundance. The carbides of silicon and titanium are extremely hard, the latter even cutting diamond.

TECHNICAL NOTES.

Carbon boride is a new compound of the electric furnace, obtained by H. Moissan, by the heating action of the current in a suitable mixture of boracic acid and carbon. The mode of production is strictly analagous to that of the well-known substance carborundum, or carbon silicide, made by heating in the electric furnace a mixture of silica and carbon.

The new product is reported to possess a degree of hardness superior to that of the diamond, which it readily cuts, and to have the great advantage that it is possible to produce it in pieces of any desired size.

ELECTRIC FURNACE STUDIES.

In the current number of the *Annales de Chimie et de Physique*, M. Moissan continues the account of his researches with the electric furnace. He gives the preparation and properties of titanium, molybdenum, uranium and the borides of iron and of carbon, the preparation of manganese, and an historical account of the researches already made on the crystallized carbides of the alkaline earths. In the latter paper he lays claim to the discovery of crystallized carbide of calcium, while assigning to Mr. Willson the credit of having introduced its manufacture in the United States. With regard to titanium, M.

Moissan has found that with a current of 50 ampères and 50 volts, titanic acid is converted into crystallized oxide of titanium. With 350 ampères and 70 volts, the bronze-yellow nitride, Ti_2N_2, is obtained. When 1,200 ampères and 70 volts are used, the temperature rises above the point of decomposition of this substance, and the carbide TiC is formed, free from nitrogen; and if this is heated with an excess of titanic acid, titanium containing only 2 per cent. of carbon is obtained. These successive actions, says M. Moissan, give a decisive proof of the increase of temperature of the electric arc dependent on an increase of the current, and form the starting point of another long series of experiments. The preparation of the crystallized compound of iron and boron containing over 15 per cent. of boron, and nearly corresponding to the formula FeB, effectually disposes of the assertion of some workers on iron that it is impossible to alloy these two elements.

THE DANUBE SHIP CANAL.

The great engineering work of removing what is known as the "Iron Gates" in the River Danube has been completed, says the *Scientific American*, and on September 27th the new canal was formally thrown open to navigation, with elaborate ceremonies, by Emperor Francis Joseph. His Majesty was accompanied by King Carl, of Roumania, and King Alexander, of Servia. The procession of steamboats which passed through the Iron Gates showed how successfully the work of removing the obstacles to navigation has been accomplished. For forty years the passage of the Iron Gates has been difficult and possible only on an average of 117 out of the 225 days during which navigation is open. The obstruction between Bazias and the Iron Gates has been removed and a canal has been excavated through the Prigada and other reefs of the Iron Gates along the southern or Servian side of the river. The canal through the rocks is about two miles long, 260 feet wide, and 10 feet deep, so that the Danube will now be navigable for the largest river steamers from Vienna to the Black Sea. The whole work cost nearly $10,000,000, and owing to carelessness in blasting operations, some 200 workmen lost their lives. The opening of the Danube to easy navigation will doubtless develop the Danube traffic to a tremendous extent. The formal opening of the canal was the crowning feature of the Hungarian millennium festival.

BOOK NOTICES.

A Text-Book on Shades and Shadows and Perspective. New York: John Wiley & Sons. 1896. By John E. Hill, M.S., M.C.E. 2d edition. 8vo. Pp. 101. 12 plates.

This book is a thoroughly scientific treatment of the subject, and, as the author says, follows descriptive geometry as a logical sequence. For those who believe in and admire the usual collegiate method of training students

in constructive drawing, it is admirable; but to the practical man, who has had a share in doing the world's work, it seems like a waste of the time and energy of the student to make him learn principles, definitions, conventions and an elaborate notation, the application of which he cannot understand until he gets well into the succeeding chapters, and then work out difficult and intricate problems to attain ends which are of no real value. Descriptive geometry is a beautiful science, but it needs revolutionizing on the lines of its useful application to actual work; but so long as all four of the diedral angles are considered and the first angle is made the principal one, when the accepted rule of practice is the third, this is impossible. Planes of projection are imaginary planes, and the practical man would be as apt to draw the shadow of an object on them as to draw the shadow it throws upon space; but when this shadow reaches both the co-ordinate planes and is so delineated, he considers that the height of absurdity is reached.

It is an unfortunate truth, generally recognized, that technical graduates on entering their careers are more poorly equipped in their draughting capabilities than in any other branch of their professions, and this is largely due to their being crammed with an enormous amount of elaborate science, which they only half understand and thoroughly dislike, instead of having their inventive faculties cultivated, and being trained to put their ideas on paper in a clear, detailed, common-sense manner, so as to be easily understood and accurately executed. In the rare cases, where shadows are called for in practice, this book would be useful for reference, but as a part of a technical course it excites profound sympathy for the unfortunate student.

W. H. T.

Alternating Currents and Alternating Current Machinery. Volume II of the Text-Book on Electro-Magnetism and the Construction of Dynamos. By Dugald C. Jackson, C.E., Professor of Electrical Engineering in the University of Wisconsin, and John Price Jackson, M.E., Professor of Electrical Engineering in the Pennsylvania State College. New York: The Macmillan Company. (New York, 66 Fifth Avenue.) 1896. 729 pages, including index. $3.50.

Students of engineering, and of that branch of the profession which has to do with the construction of alternating current machinery, will welcome this addition to the literature on the subject of alternating currents.

The ability to select the general principles from the unimportant and particular matter marks the successful author.

The general plan of the book is to give, first, the underlying principles o electro-magnetism as applying to alternating currents, and then to make the application of these principles to the practical design of machines. The rules and expeiimental data of good practice have been widely gathered and introduced, yet descriptions of historical and commercial machinery are included only in so far as they stand as types of classes.

Special attention is called to the graphical solution of problems in alternating currents. While mathematics are practically a means to an end, many

persons cannot reason in a purely mathematical way, well enough for the analytical solution. To these the graphical method appeals to the reason through the eye, and to those accustomed to abstract reasoning, the graphical solution will be found to be a material aid.

The book is profusely illustrated with diagramatical drawings. In short, both in the text and in the illustrations, there has been a cutting away of the unnecessary and a boiling down until only the essential remains. In footnotes, the authors refer the reader to articles in current engineering literature for detailed descriptions on special subjects.

The student will find in this work a text-book, and the engineer a book of reference. H. J. L.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, November 18, 1896.*]

HALL OF THE FRANKLIN INSTITUTE,

PHILADELPHIA, November 18, 1896.

HENRY R. HEYL, Vice-President, in the chair.

Present, 184 members and visitors.

Addition to membership since last report, 1.

Acceptances of election to membership in the Committee on Science and the Arts were presented from Messrs. John Birkinbine, Wm. C. Henderson, Thomas Spencer and Wm. R. Webster.

Mr. Wm. T. Lewis, President of the Horological Society of Philadelphia, read a paper presenting some "Observations on Magnetized Watches." The speaker exhibited, with the aid of the projecting lantern, the results of an experimental study of the subject. (Referred for publication.)

Mr. Louis E. Levy described and illustrated the improvements in glass-gratings for half-tone engravings, devised jointly by himself and Mr. Max Levy. (Referred, for investigation and report, to the Committee on Science and the Arts.)

Prof. Samuel McCutcheon described and exhibited in operation an improved acetylene gas machine, made by the Pennsylvania Acetylene Gas Machine Company.

Mr. Charles F. Chase described and exhibited in operation the Heintz steam-trap. (Referred, for investigation and report, to the Committee on Science and the Arts.)

The Secretary gave some account of the new suspension bridge about to be built over the East River.

Adjourned. WM. H. WAHL, *Secretary*.